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COMPARATIVE TESTS ON SCREW PROPELLERS.

BY PROF. H. LORENZ, PH. D.

Translated from the "Zeitschrift des Vereines deutscher Ingenieur," by WILLIAM WACHSMANN, Associate Member.

TRANSLATOR'S NOTE.—The following theory of the screw propeller was presented for the first time in a paper at a meeting of the Shiffbautechnische Gesellschaft in 1905, a copy of which the author was kind enough to place at my disposal. The present article, which is a translation from the "Zeitschrift des Vereines deutscher Ingenieure," is a simplification of the theory given in the foregoing paper, at the same time due regard has been given to the wake current. Prof. Lorenz presents a new theory on the screw propeller containing exact founded statements upon the shape of the blade and the variability of the pitch in both an axial and radial direction. The theory is based upon the fundamental principles of hydrodynamics, employing especially the formula of continuity and the formula of moments by Euler. For a more exhaustive treatment of the screw-propeller theory, see the author's treatise on "A new theory and method of calculating gyroscopic discs," Munich and Berlin, 1906, Chap.

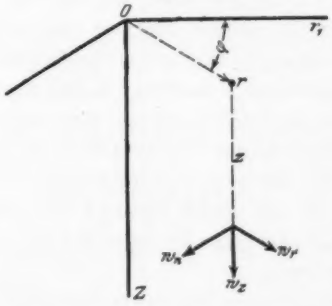
III. Prof. H. Lorenz is a member of the faculty of the Polytechnic High School in Danzig, Germany, and belongs to the modern school of investigators and writers on theoretical and applied mechanics.

I. *Preliminary Remarks.*—The action of a ship's screw propeller is based upon the reaction produced against the ship by the acceleration of the water to the stern, at the same time the variation of the hydraulic pressure is quite unimportant. Up to the present time the calculation for screw propellers has been limited to ascertaining the pitch for a given screw surface from the number of revolutions and the relative variation in velocity of the water current in which the screw revolved. By introducing the so-called "slip," that is, a factor derived from experience, it was endeavored to justify, on the one hand, the differences between the relative velocity of flow of the water and the ship's speed, and, on the other hand, the variations of the individual water paths between the blades. The shape of the blade remained entirely arbitrary, so that a great variety of shapes are encountered in practice, depending upon whether it was desired to especially use the central or external portion of the blades for performing work. The whole method evidently is devoid of all scientific principles, consequently many screws show a very unsatisfactory utilization of energy. In spite of economical engines the result is a waste of fuel, which, by taking up valuable cargo space as well as increasing the weights, places a double burden upon shipping. Moreover, difficulties are encountered when using steam turbines, mainly on account of the high rate of revolutions, the usual coefficients of experience obviously no longer being applicable to the latter.

The clearing up of this unwelcome and to be sure unworthy situation for the present state of engineering science could only be done by means of theory, by the application of the laws of hydrodynamics, especially after numerous costly experiments, which naturally could only extend over several of the usual screw forms, remained nearly without result.

Through the courtesy of the Imperial Navy Department and the management of the Imperial Dockyard at Danzig I was enabled to test in a practical manner the results gained from theory, a report of which follows.

Fig. 1.



II. *Calculation of a Screw Propeller.*—Suppose a cylindrical coödinate system be connected with the ship while in motion, Fig. 1, the z axis of which shall coincide with the center of the shaft. Let r be the distance of an element of water dm from the turning axis gliding across the surface of the screw, z its distance from the zero plane of the coördinate system, φ the absolute turning angle formed by radius vector r with the initial position coinciding with the entering radius r_1. Let the relative turning angle of the radius vector on the blade be χ, ω the angular velocity of the same, then for the element of time dt we have the following equation:

$$d\varphi = \omega dt + d\chi. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Now let the absolute component of rotation of the velocity of the water be w_u, the relative axial component w_z and the radial component be w_r, then

$$w_u = r\frac{d\varphi}{dt}, \quad w_z = \frac{dz}{dt}, \quad w_r = \frac{dr}{dt}. \quad . \quad . \quad . \quad (2)$$

With the aid of the first two of these formula, dt and $d\varphi$ can be eliminated, and formula (1) becomes

$$d\chi = -\omega \frac{dz}{w_z} + \frac{w_u dz}{r w_z}. \quad \ldots\ldots (3)$$

This equation represents the *differential equation of the screw surface sought*, but which yet remains to be integrated. It will be recognized that this equation represents an ordinary screw surface if, on the one hand, $w_u = 0$, that is, if the water possesses no rotative motion, and, on the other hand, if w_z in its passage through the screw undergoes no variation. But the latter condition is contrary to the mode of action contemplated, as we shall presently see that water possessing no rotative component cannot receive a turning moment. *From this it follows that the usual screw surface is not compatible with a passage of the water through the propeller without shock, and it must therefore be regarded as a rough approximation for its purpose.*

The integration of equation (3) is then only possible when the dependency of all the individual values of z contained in the equation are known. To simplify matters, insert constant a and put

$$w_z = 2az, \quad \ldots\ldots\ldots (4)$$

hence

$$d\chi = -\frac{\omega dz}{2az} + \frac{w_u r}{2ar^2 z} dz. \quad \ldots\ldots (3a)$$

But according to the principles on symmetrical flow around an axis the assumption made in equation (4) corresponds to a function of flow *

$$\Psi = ar^2 z, \quad \ldots\ldots\ldots (5)$$

which gives the course of the individual stream lines to each of which is adjoined a parameter Ψ.

By integrating equation (3a) along one of these stream lines Ψ will remain constant, and there would only be left to still establish the dependency of the product $w_u r$ upon z. Since the product $w_u r$ occurs only in the second term of equation (3a) and being small compared with the first term, owing to

*See "The theory and calculation of full-flow turbines and centrifugal pumps," by H. Lorenz, Z. d. V. d. I., p. 1670, 1905.

the small absolute turning motion of the water, it will suffice to again assume that the dependency is a linear one. By observing that the water in general possesses no rotative motion during entrance, then, if z_1 be the corresponding abscissa, with a coefficient b, we get

$$w_u r = b(z - z_1), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

while if z_2 be the abscissa during exit we have

$$(w_u r)_2 = b(z_2 - z_1). \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6a)$$

Finally, by combining equation (6) and (6a), it follows that

$$w_u r = (w_u r)_2 \frac{z - z_1}{z_2 - z_1}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (6b)$$

With this equation as well as with equation (5) equation (3a) can be written

$$d\chi = -\frac{\omega}{2a}\frac{dz}{z} + \frac{(w_u r)_2}{2\Psi}\frac{z - z_1}{z_2 - z_1}dz, \quad . \quad . \quad . \quad . \quad (3b)$$

integrating this equation along the stream line Ψ:

$$\chi = -\frac{\omega}{2a}\lg\frac{z}{z_1} + \frac{(w_u r)_2}{4\Psi}\frac{(z - z_1)^2}{z_2 - z_1}, \quad . \quad . \quad . \quad . \quad (7)$$

which combined with equation (5) gives the screw surface. To utilize this formula there must be known, besides the angular velocity ω and the axial propeller length $z_2 - z_1$, the constants a and $(w_u r)_2$ as well as the corresponding parameter Ψ of each stream line. Now let P be the propeller thrust, which is identical with the resistance of the ship, let w_{s1} be the relative entering velocity of the water into the screw, and w_{s2} that of the exit of the water from the screw; then, if $g = 9.81$ m/sec^2 be the acceleration due to the earth's gravity, and Q the volume of water in kilos. per sec., we have

$$P = \frac{Q}{g}(w_{s2} - w_{s1}). \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

In this equation w_{s1} is less than the ship's speed c by an amount equal to the so-called wake current, which to some

extent introduces an uncertainty into the entire calculation. But by equation (4) equation (8) becomes

$$P = \frac{Q}{g} 2a(z_2 - z_1), \quad . \quad . \quad . \quad . \quad . \quad . \quad (8a)$$

from which a can be determined if Q be known. Let r_1' be the external radius of the propeller at the entering area, and r_1'' that at the hub, then, if γ be the specific weight of the water, evidently

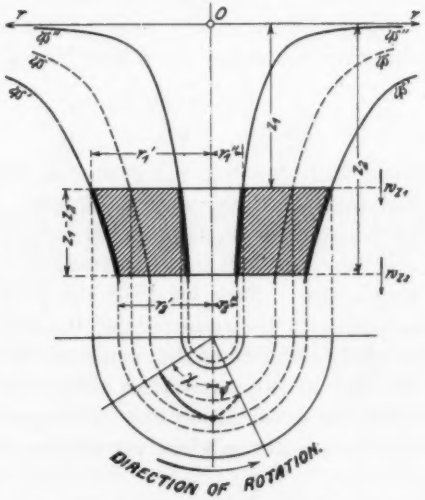
$$Q = \pi \gamma w_{s1} (r_1'^2 - r_1''^2). \quad . \quad . \quad . \quad . \quad (9)$$

For equations (4) and (5) we can in general subsitiute:

$$Q = 2\pi\gamma(\Psi' - \Psi''), \quad . \quad . \quad . \quad . \quad . \quad (10)$$

which merely expresses, *that the difference in the parameters of the stream lines at the periphery and the hub determines*

Fig. 2.



the volume of flow. By determining the volume of flow Q from equation (9) for given radii r_1' and r_1'' as well as an assumption for the wake w_{s1}, we get from equation (8) the

increase in velocity $w_{z2} - w_{z1}$ and hence the absolute value of w_{z2} if the resistance of the ship P be known. On the other hand, equation (8a) also gives the value for the constant a, with which the absolute value of the abscissa z_1 and z_2 for the entering and leaving areas are obtained from equation (4). Then with radii r_1' and r_1'' the two parameters Ψ' and Ψ'' (forming the inner and outer boundaries of the stream lines of the propeller) are also established from equation (5); the meridian section of these stream lines can now be drawn, see Fig. 2.

We shall now proceed to determine the value of $(w_u r)_2$. According to the equation for moments from the turbine theory of Euler the variation of $w_u r$ represents the turning moment per unit of mass of water flowing through the propeller; consequently $\omega d(w_u r)$ is the corresponding element of work to be introduced. This work is utilized, on the one hand, to overcome the resistance of the ship, which according to equation (8) consumes an amount equal to cdw_z for a speed c of the ship, but, on the other hand, it is also used to increase the kinetic energy of the water, so that we also have

$$\omega d(w_u r) = cdw_z + wdw,$$

if w represents the absolute velocity of the water.

To simplify matters we shall consider the unavoidable loss due to friction on the propeller blades as additional work to drive the ship, let it be regarded by a coefficient $\xi > 1$. The equation of energy will then assume the form of

$$\omega d(w_u r) = \xi cdw_z + wdw \quad . \quad . \quad . \quad . \quad (11)$$

integrating, we get

$$\omega (w_u r)_2 = \xi c(w_{z2} - w_{z1}) + \tfrac{1}{2}(w_2^2 - w_1^2). \quad . \quad (11a)$$

Since the absolute total velocity is in general expressed by

$$w^2 = (w_z - c)^2 + w_u^2 + w_r^2, \quad . \quad . \quad . \quad . \quad (12)$$

and considering the fact that the water upon entering the propeller possesses no energy of rotation, we have

$$\left.\begin{aligned} w_2^2 &= (w_{z2} - c)^2 + w_{r2} + w_{u2}^2 \\ w_1^2 &= (w_{z1} - c)^2 + w_{r1}^2 \end{aligned}\right\}, \quad . \quad . \quad . \quad (12a)$$

consequently

$$w_2^2 - w_1^2 = (w_{z2}^2 - w_{z1}^2) - 2c(w_{z2} - w_{z1}) + (w_{r2}^2 - w_{r1}^2) + w_{u2}^2. \quad . \quad (12b)$$

In this equation the difference $w_{r2}^2 - w_{r1}^2$ can in nearly all cases be practically neglected, since at the stern there already exists a sufficient radial velocity due to the motion of the water around the ship, which more than likely will be still further decreased in passing through the propeller. In this way equation (12b) will become much simplified, and substituting it in equation (11a), we get

$$\omega(w_u r)_2 = (w_{z2} - w_{z1})\left(c(\xi - 1) + \frac{w_{z2} + w_{z1}}{2}\right) + \frac{w_{u2}^2}{2}. \quad (13)$$

Besides the product $(w_u r)$ the square of w_u^2 also occurs in this formula; consequently to be exact it is not possible for $(w_u r)$ to be solely dependent upon z according to our assumption made in equation (6).* However since $w_u r$ affects only the corrective term in the equation for the blade surface and w_{u2}, moreover, being usually small, we will be permitted to hold on to our assumption as approximate if we introduce an average value for w_{u2}^2 in equation (13), which can be readily computed at

$$w_{u2}^2 = (w_u r)_2^2 \frac{\lg r_2' - \lg r_2''}{r_2'^2 - r_2''^2}, \quad . \quad . \quad . \quad . \quad (14)$$

in which r_2' and r_2'' represent the outer and inner radius of the

* Hence this holds good for all kinds of axial-flow wheels, the proof of which I have given in my book on a "New theory and calculation of gyroscopic discs," Munich and Berlin, 1906, R. Oldenbourg; for radial flow wheels the calculation can be approximately carried out. Moreover, from the requirements of real roots for equation (13), still another condition follows for the least radius for the propeller hub, of which I have not availed myself in the following example, since it was impossible to use the corresponding thickness of hub without materially disturbing the water stream at the stern of the ship. Consequently, in the vicinity of the hub, it became necessary to deviate slightly from the true theoretical shape of the blade, without this having any noticeable influence on the action of the screw. In connection with this compare also with the "Theory and calculation of propeller fans," by H. Lorenz, 'Zeitschrift fur Turbinenwesen,' 1906, No. 22.

exit area. All data are now given for using equation (7) for purposes of calculation, and nothing remains to prevent the plotting of the *screw surface* sought. It will be easily recognized that *this surface shows an increasing pitch from forward towards aft and from the periphery towards the hub, while the radii at the leaving edge of the blades become smaller than the radii at the entering edge corresponding with the relative increase in velocity of the water stream.*

Finally the *efficiency* of the propeller as a quotient of the useful work Pc and the work expended

$$L = \frac{Q}{g}\omega\,(w_u r)_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

with regard to equation (8) can be computed at

$$\eta = \frac{(w_{z2} - w_{z1})c}{\omega\,(w_u r)_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

As an example we shall at once proceed to calculate the propeller which was later on used for the comparative tests. The speed of the boat for this propeller was $c = 4.25$ meters per second, the resistance $P = 415$ kilos. The normal number of revolutions per minute of the engine was $n = 286$, from which can be computed the angular velocity $\omega = 30$ meters. The greatest permissible radius was $r_1' = 0.425$ meters, the axial length $z_2 - z_1 = 0.17$ meters.

If the wake be assumed at 12 per cent., then the relative entering velocity of the water in the propeller will amount to $w_{z1} = 3.75$ meters per second. With $r_1'' = 0.11$ meters as a radius for the hub, the propeller according to equation (9) takes hold of a volume of water $Q = 1{,}985$ kilos. per second, which according to equation (8) receives a relative exit velocity of $w_{z2} = 5.8$ meters per second. Further, with the given axial length $z_2 - z_1 = 0.17$ meters we get from equation (8a) the constant of the stream function $a = 6.05$, and hence from equation (4) the distances $z_1 = 0.311$ meters, $z_2 = 0.481$ meters of the entering and leaving planes of the propeller from the zero plane of the coördinate system. According to equation (5) the

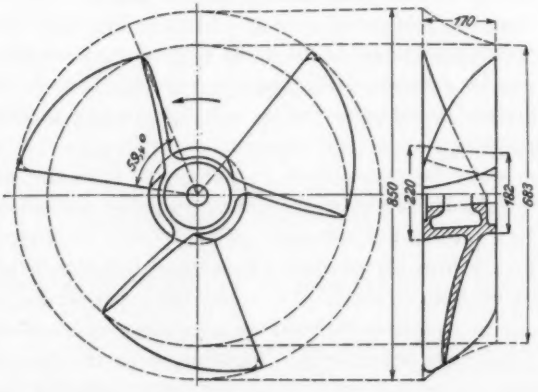
parameters of the outer and inner stream lines are $\Psi' = 0.3385$ and $\Psi'' = 0.0227$, from which $\Psi' - \Psi'' = 0.3158$ is obtained, and again corresponding to equation (10)

$$2\pi\gamma(\Psi' - \Psi'') = 1{,}984 = Q$$

is obtained. Then by neglecting $\frac{1}{2} w_{z2}^2$ and assuming $\xi = 1.1$ (that is, allowing 10 per cent. of the ship's resistance for friction and edge resistance), we get from equation (13) $\omega(w_u r)_2 = 10.66$. With the two exit radii $r_2' = 0.342$ m. and $r_2'' = 0.089$ m. determined from equation (5), we then obtain from equation (14) the average value $\frac{1}{2} w_{u2}^2 = 0.24$, with which $\omega(w_u r)_2 = 10.9$ and $(w_u r)_2 = 0.363$ are finally obtained from equation (13). Substituting this value with those determined in the foregoing for a, z_1, z_2 as well as the parameters Ψ' and Ψ'' in equation (7), then, for the two vane angles at the outer and inner edge, we obtain

$$\chi_2' = -1.037 \text{ or } 59.4°, \quad \chi_2'' = -0.40 \text{ or } 24°.$$

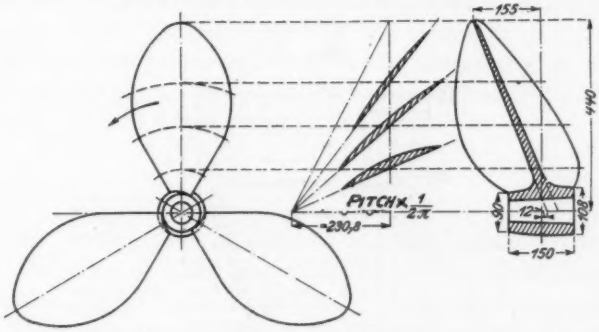
Fig. 3 und 4. NEW PROPELLER.



In the same manner, then, any number of intermediate points can be calculated with other values for $z_2 > z > z_1$ as well as for $\Psi' > \Psi > \Psi''$, whereupon the laying down of the propeller can proceed, Fig. 3 and 4. The work expended by

the propeller is, according to equation (15), $L = 2{,}205$ meter kilos. per second or 29.4 PS_e (effective horsepower), while the work gained in $Pc = 1{,}764$ meter kilos. per second or 23.5 PS_e (effective horsepower), consequently, according to equation (16) the efficiency is $\eta = 0.8$.*

Fig. 5 und 6. OLD PROPELLER.



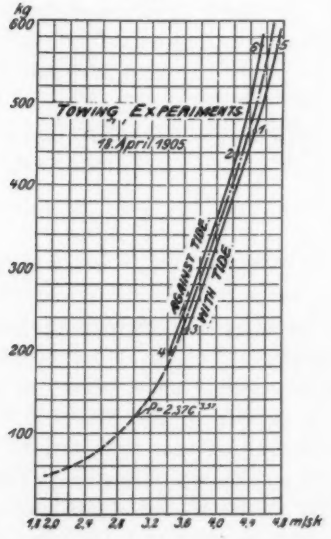
III. *The Tests.*—For the purpose of carrying out the tests with a propeller based upon the foregoing theory the Imperial Dockyard at Danzig, after the Imperial Navy Department had allowed the necessary funds, placed at my disposal the *Ferry Boat IV* in service of the Machine Construction Department. The length of this boat was 12 meters, breadth 2.8 meters, depth 0.75 meters at about 11 tons displacement. It was fitted with a three-bladed screw having a diameter of 880 mm. and a uniform pitch of 1,450 mm. The engine was of the compound type, having a high-pressure cylinder of 150 mm. diameter, low-pressure cylinder 280 mm. diameter, and a

* In the "Zeitschrift des Vereines deutcher Ingenieure," 1907, p. 589, Prof. Lorenz corrects an error in the foregoing example worked out for a screw propeller, viz:—from equation (14) obtain $w\,n_s{}^2 = 1.55$ instead of 0.24, hence the final value of $\omega(w\,n\,r)_s = 12.21$ instead of 10.9. Since this only affects the corrective term of equation (7), the shape of the propeller will not be sensibly changed, the hydraulic efficiency, however, will be changed, which now becomes $\eta = 0.71$. In consequence of the greater wake the efficiency was, as a matter of fact, somewhat higher. This follows from another article by the same author on "The variation of the revolutions and the efficiency of screw propellers with the speed," "Zeitschrift des Vereines deutscher Ingenieure," 1907, p. 329. The efficiency, according to Table 3 of this article, was about 0.76.—W. W., Transl.

common stroke of 200 mm.; the boiler was of the water-tube type and carried a working pressure of 9 atmospheres.

On April 5, 1906, this boat was given a number of runs over a 940-meter course in the Emperor's Harbor at Danzig, and again on May 23, 1906, after having made some change in the valve gear of the engine. The results of these runs are given in Table 1. Runs were made in both directions over the trial course with a start of about the same length as the course which was

Fig. 7.



in a state of rest. During the runs the engines were indicated as often as possible; in addition to this the total number of revolutions were determined, and as a check the runs were timed by taking readings from a chronoscope, graduated to one-fifth seconds, by two independent observers. The indicators used for ascertaining the horsepower were obtained from the yard; they were new and of the Maihak design equipped with outside springs. To determine the resistance of the boat, towing experiments were made April 18, 1906, in the Gulf of

Danzig, after the screw had been removed. The results of these experiments are given in Table 2, graphically they are represented in Fig. 7. With respect to the lively traffic these experiments could not be conducted in the Emperor's Harbor on account of the long tow line; no doubt could be raised against the transference of the results obtained in the Gulf to those in the Emperor's Harbor, since the depth of the water on both courses was about the same (7.5 to 8 meters). During the experiments the resistance was read from a dynamometer which had been previously tested for its correctness by loading it with weights. Moreover, the experimental results could be easily verified by the empirical rule

$$P = 2.37\, c^{3.57}.$$

After having thus established all the fundamentals for the calculation of a new propeller, the same could be done as presented in the foregoing manner. However, it was necessary to restrict the diameter to 850 mm. as against 880 mm. of the existing screw, since the heel for supporting the rudder on the stern post offered insufficient space, and to incline the blades aft appeared irreconcilable with my theory. Finally, in fitting the propeller (which was made of bronze in the shops at the yard, and which was a very smooth job), it became necessary to round off the corners of the entering edge, since the actual construction of the ship did not quite agree with the drawing. Through this twofold reduction in sectional area the new propeller was put at a great disadvantage in comparison with the old one, since, naturally, to overcome the same resistance it had to impart a higher exit velocity to a smaller volume of water. In spite of this fact the trials carried out on August 1 and August 4, 1906 (the detailed results of which are evident from Table 3), showed that the new propeller was far superior at all speeds. This is especially clear from the curves shown for the performances, Figs. 8 and 9, as well as from curves for the total efficiencies, Figs. 10 and 11, given as function of the speeds and revolutions. Under the

total efficiency η_o is to be understood the ratio of the effective work of resistance determined from the towing experiments to the indicated horsepower of the engine; consequently it includes the hydraulic efficiency of the propeller as well as the

Fig. 8.

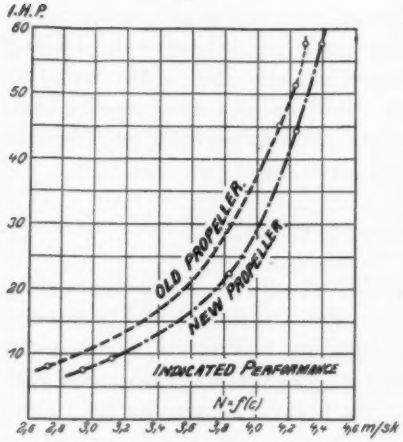


Fig. 9.

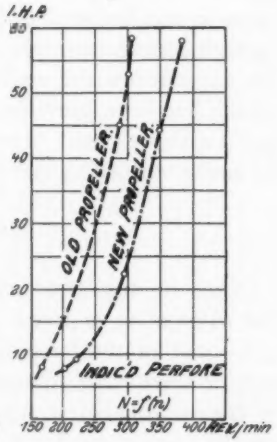


Fig. 10.

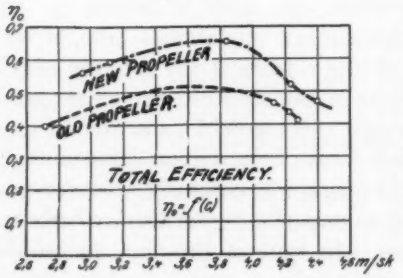
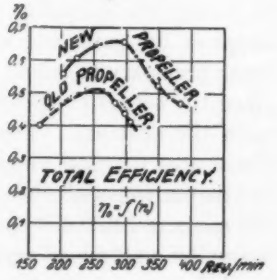


Fig. 11.



mechanical efficiency of the engine and shafting. The total efficiency attained its maximum value of 0.65 for the designed revolutions of 280 to 290 per minute, during which the speed amounted to only 3.7 to 3.8 meters per second, while for a speed of 3.8 meters per second, the revolutions increased to

360 per minute, the total efficiency falling off to 0.51.* The cause of this one deviation of the behavior of the propeller can be attributed to the subsequent diminution of the sectional area by rounding off the corners (about 5 per cent.), but above all to the undervaluation of the wake current, which was assumed at about 12 per cent., of the ship's speed, but which really amounted to about 20 per cent., on account of the rather full lines of the ship. In the light of this experience no further difficulties would be anticipated in the future to select the proper number of revolutions beforehand.

In any case, however, the foregoing experiments have shown that it is possible to calculate screw propellers based upon hydrodynamic principles, the hydraulic efficiencies of which are not far behind those of good turbines. To establish this fact the Imperial Navy Department, by granting the means for the construction of the propeller and carrying out the experiments, has undoubtedly rendered a meritorious service. But I am especially indebted to Privy Naval Construction Councillors Hossfeld and Uthemann, of the Imperial Navy Yard at Danzig, for their energetic promotion of the trials, as well as to Naval Constructor Jensen and my assistant Dr. Eng. A. Proell, for their untiring coöperation during the same.

Tables of experimental runs, on following pages.

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*This result is in satisfactory agreement with the figures obtained at the conclusion of the foregoing chapter, if the mechanical efficiency of the engine, including the shafting, varies between 0.82 and 0.70 during the interval of 290 to 360 revolutions per minute. In respect to this question, see my article on "*The variation of the performance of reciprocating engines with the revolutions*" "Zeitsch. d. v. d. Ing." 1906, p. 1277. On account of the impact action and the increasing friction of the water the efficiency of the propeller might even be decreased by about 10 per cent. within this sphere.

Table I.—EXPERIMENTAL RUNS WITH THE ORDINARY PROPELLER.

Date of run.	Number and direction of run.	Revolutions.	Mean effective pressure.		I.H.P.		Total I.H.P.	Speed.		Resistance of the ship P, kilos.	Total efficiency η_o.	Remarks.
			H.P. cylinder. Kilos. per sq. cm.	L.P. cylinder. Kilos. per sq. cm.	H.P. cylinder.	L.P. cylinder.		Meters per second.	Knots.			
May 23, '06..	7. South.	170	1.15	0.636	3.0	5.9	8.9	2.857	5.55	...	...	
	8. North.	163	1.05	0.56	2.62	4.95	7.57	2.582	5.02	...	...	
Mean.....	...	167	...	...	...	...	8.23	2.72	5.28	90.5	0.4	Light wind.
April 5, '06..	1. North.	292	5.0	1.645	22.4	26.1	48.5	3.98	7.75	...	...	Against wind.
	2. South.	282	4.94	1.52	21.5	23.4	44.9	4.27	8.30	...	...	With wind.
	3. North.	285	4.78	1.465	21.0	22.7	43.7	4.00	7.76	...	...	Against wind.
	4. South.	288	4.74	1.43	21.0	22.4	43.4	4.27	8.30	...	...	With wind.
Mean.....	...	286.7	...	...	...	...	45.12	4.13	8.03	380.0	0.465	Strong wind.
May 23, '06..	5. South.	299	4.45	1.935	20.48	31.48	51.96	4.225	8.213	...	...	
	6. North.	296	4.51	2.06	20.55	33.18	53.73	4.219	8.2	...	...	
Mean.....	...	297.5	...	...	...	...	52.84	4.222	8.207	411.0	0.437	Light wind.
May 23, '06..	9. South.	305	4.96	2.1	23.28	34.86	58.14	(4.28)	(8.32)	(425)	(0.415)	Speed and resistance taken from Figs. 8 to 11.

TABLE 2.—TOWING EXPERIMENTS OVER A MEASURED COURSE (1½ SEA MILES) IN THE GULF OF DANZIG, APRIL 18, 1906.

Number and direction of run.	Duration of one run.	Speed.		Resistance P, kilos.	Revolutions per min. of the towing engine.	Remarks.
		Meters per sec.	Knots.			
1. North.....	10 min., 24 sec.	$C_0 = 4.46$	8.66	465	82	With stream and wind.
2. South.....	10 55	$C_0 = 4.25$	8.25	439	84	Against stream and wind.
3. North.....	12 41	$C_0 = 3.65$	7.09	225	67	With stream and wind.
4. South.....	13 33	$C_0 = 3.42$	6.64	197	67	Against stream and wind.
5. North.....	9 47	$C_0 = 4.74$	9.20	572	90	With stream and wind.
6. South.....	10 14	$C_0 = 4.53$	8.79	570	90	Against stream and wind.

TABLE 3.—EXPERIMENTAL RUNS WITH THE NEW PROPELLER.

Date of run.	Number and direction of run.	Revolutions.	Mean effective pressure.		I.H.P.		Total I.H.P.	Speed.		Resistance of the ship P, kilos.	Total efficiency, η_c.	Remarks.
			H.P. cylinder. Kilos. per sq. cm.	L.P. cylinder. Kilos. per sq. cm.	H.P. cylinder.	L.P. cylinder.		Meters per second.	Knots.			
Aug. 1, '06....	5. North...	205.0	0.95	0.43	3.0	4.8	7.8	2.99	5.81	.....	.....	Without awning.
	6. South...	201.0	0.905	0.445	2.8	4.85	7.65	2.89	5.62	.....	.....	Without awning.
Mean.....	.....	203.0	.....	.....	.....	.....	7.725	2.94	5.72	111	0.56	Light wind.
Aug. 4, '06....	9. South...	227.0	1.15	0.457	4.3	5.47	9.5	3.12	6.06	.....	.....	With awning.
	10. North...	220.0	1.125	0.443	3.81	5.29	9.1	3.10	6.03	.....	.....	With awning.
Mean	.....	223.5	.....	.....	.....	.....	9.3	3.11	6.05	135	0.60	Almost calm.
Aug. 1, '06....	1. North...	290.0	1.75	0.881	7.85	13.85	21.73	3.82	7.43	.....	.....	With awning.
	2. South...	297.0	2.06	0.848	9.43	13.69	23.12	3.84	7.46	.....	.....	Without awning.
Mean	.....	293.5	.....	.....	.....	.....	22.425	3.83	7.445	289	0.657	Light wind.
Aug. 1, '06....	3. North ..	346.0	3.15	1.545	16.78	29.09	45.87	4.27	8.3	.....	.....	Without awning.
	4. South...	340.0	3.00	1.445	15.70	26.74	42.44	4.18	8.125	.....	.....	Without awning.
Aug. 4, '06....	7. South...	351.5	3.22	1.455	17.40	27.82	45.22	4.18	8.125	.....	.....	With awning.
	8. North...	356.0	3.22	1.333	17.64	25.80	43.44	4.23	8.222	.....	.....	With awning.
Mean	.....	348.4	.....	.....	.....	.....	44.23	4.218	8.2	408	0.521	
Aug. 4, '06....	11. South...	383.0	3.52	1.79	20.6	37.1	57.7	4.372	8.5	.....	.....	With awning.
	12. North...	381.0	3.58	1.755	21.1	36.6	57.7	4.413	8.59	.....	.....	With awning.
Mean	.....	382.0	.....	.....	.....	.....	57.7	4.393	8.54	464	0.472	With awning.

THE TURBINE AND RECIPROCATING ENGINE FOR NAVAL PURPOSES.

By Lieutenant W. G. Diman, U. S. Navy, Member.

It has been fairly well proven that for land purposes and for merchant vessels of high power and speed the turbine has given satisfactory results from an economical standpoint. A turbine under these conditions runs at maximum speed and maximum power. A passenger ship leaving port starts out under full-power conditions and remains under the same conditions until she arrives at the next port, time of passage meaning money to the owners.

For naval purposes the installation of turbine machinery is an entirely different proposition. A ship is built to fight, and should be able to maintain the greatest speed possible if called upon under the best conditions. A ship built may never be called into a naval fight, but no one can tell when the day will come when the machinery may be called upon to perform its greatest power. It may be only for an hour or two, but this hour may mean victory or defeat.

If run at *maximum* speed the turbine may be the best available. The question, however, arises, which would be the better for all-around work both at low and high speeds and give as good results in cases of emergency. It may be admitted that for maximum speeds the turbine has a little the better of the argument; but for all-around cruising, and taking into consideration the installation of machinery, I think the reciprocating engine up to the present time is the better installation.

If two shafts are installed in the ship and on each shaft one turbine of a large unit, the economy is sure to drop when the speed drops, and at low power the economy will be greatly decreased because a large unit cannot be satisfactorily designed to give economical results at all speeds. The maximum peripheral speed at the buckets in marine work is commonly much

less than one-half that of a turbine employed for electric lighting, and if the same general design were followed in the two cases the turbine should be at least four times as long if equal economy were to be obtained. In order to gain a low peripheral speed at a moderate number of revolutions, the diameter of the turbine has to be increased, which means a marked increase in the weight of machinery. If two turbines are placed on each shaft, with a H.P. and a L.P. on each shaft, the economy may not fall as much, but it is sure to fall at the lower speeds and greatly exceeds that of a properly designed reciprocating engine at low powers. If three or four shafts are installed, or even with two shafts, combinations may be made whereby cruising turbines are installed, and the economy may be obtained at the lower speeds which will correspond closely to that of the reciprocating engine. As these economical results are obtained, what is done to obtain them? More turbines of smaller units have to be installed, more shafting, more piping, with joints, and increase of valves, and the whole equipment has to be increased and complicated. It becomes a question whether to obtain this economy at the lower speeds equal to that of a reciprocating engine (it is doubtful whether it is obtained) this increase of machinery and complications will offset any gain which is claimed by the turbine. The less the amount of machinery on board and the less complicated it is, the easier will it be to handle and care for. The machinery on board a man-of-war at the present time is complicated enough without adding any more complications to it.

For naval purposes under ordinary conditions a ship rarely cruises at maximum speed. The ordinary cruising is around 10 or 12 knots, which is, say, 15 per cent. to 20 per cent. of full power. At this speed the cruising turbines would be practically the only ones in use and the others would run idly. With the reciprocating engine the economy can be regulated by using the cut-offs so that no change is necessary by making any change in the combination of the motive power. For these lower powers the economy of the reciprocating engine is decreased but slightly. For maximum speed the reciprocating

engine could be built to make the speed required and at the same time be economical. If all possible refinements in design that tend to economy are made, the reciprocating engine could be nearly, if not quite, as economical as the turbine. These refinements consist in the reduction of clearances, proper proportioning of the sizes of the cylinders, care in providing smooth exits through ports and passages, longer stroke, if possible, better condensing apparatus and the use of superheated steam. With high-class land engines, owing to the use of Corliss and drop types of steam valves, the clearance spaces have been much reduced. I do not see why Corliss valves, or something on that style, could not be used for marine engines. They might be placed in the tops of the cylinders. If as many experiments as are being made at the present time on the turbine were made on the reciprocating engine, I think an increase in the economy would be shown with the reciprocating engine.

Working out the water rates of about ten ships in the United States Navy, the average gives about 17.2 pounds of water per I.H.P. for main engines only. This is at maximum power under service conditions. Assuming that the water consumption was greater than this, say 19 pounds (which is quite high and perhaps ought to be about 17.5 to 18 pounds), this would give for a 20,000-I.H.P. engine a water consumption per hour of 380,000 pounds. Assuming that the boilers evaporated 9.5 pounds of water per pound of coal, then the amount of coal burnt per hour for the main engines would be 17.8 tons. Now assume that the turbine installation of 20,000 gives a water consumption *under service conditions* of 15 pounds, this will mean a water consumption per hour of 300,000 pounds, which, assuming as before the same evaporation per pound of coal, would mean a consumption of 14.1 tons of coal per hour. With the increase in auxiliaries required for the turbine this would be brought a little higher. This will show an increase in economy on the side of the turbine at the high speeds, but how long are either going to run at those top speeds? The reports of the economy of the turbine show the gain at the maximum speeds, but reliable information is not obtained, as

a general rule, for the lower speeds, and it does not appear that the turbine has beaten the reciprocating engine in *overall efficiency*—that is, taking into consideration the engine and screw together. The degree of economy of the turbine in marine practice must compete on the largest scale with that of a quadruple-expansion engine expanding saturated steam with 210 pounds fifteen times into a vacuum of 25½ inches, with an economy of 13.6 pounds of water per I.H.P. per hour.

Another question to enter into the installation of a turbine or reciprocating engine is that of the relative propeller efficiencies. It is claimed by some that the high-speed turbine will give a smaller screw and thereby get deeper immersion of the blades and less draught to the ship. This may be well enough for torpedo boats and vessels with shallow draught, but for larger vessels larger screws are needed. With propellers for turbines running at high speeds it is just a question how fast the water will flow to the screw. In a small turbine the revolutions have to be high in order to get the peripheral blade speed. As soon as the revolutions increase above that designed the efficiency of the screw decreases and cavitation losses may also enter. It is a difficult question to design a screw that will meet all the demands of a naval vessel. The thrust may be divided among three screws, but this will increase the machinery installation and complicate matters. The larger the screw, the greater the efficiency. If a blade of standard width gives insufficient surface, to prevent cavitation then either the blades have got to be made wider, other things remaining the same, or a larger pitch ratio must be chosen, which will mean an increase in the diameter of the screw and reduction in the revolutions, which means an increase in the diameter of the turbine and an increase in the weight. For marine turbines the vane speed can hardly exceed 200 feet without great sacrifice to the propeller efficiency, and is generally from 140 feet to 100 feet. If the revolutions are, say, 250 r.p.m., then the corresponding turbine diameter would be 10 feet 7 inches, and if the revolutions were decreased to 200, then the diameter of the turbine would be 13 feet 4 inches. A

screw may be designed for a turbine with a certain speed, but as the speed decreases the economy is lost in the turbine, and the screw will also lose its efficiency when the revolutions for which it is designed vary to any great extent. At high speeds of revolution the propeller efficiency drops very materially and, as a general rule, the gain in economy is counterbalanced by the loss in propeller efficiency.

In land service an arrangement is now being tried with a low-pressure turbine working in conjunction with a reciprocating engine, the low-pressure turbine being placed so as to use the exhaust from the reciprocating engine. This is giving satisfactory results and has secured great gains in the economy of steam. With the reciprocating engines as now used in the naval service, at high speeds, the vacuum does not have a great deal of effect in the power of the engine. This is due to the small size of the ports and the quick opening and closing of the valves. To get the full effect of the vacuum it would mean increasing the size of the valves to such an extent that it would be impracticable. If a low-pressure turbine was placed so as to take the exhaust from the main engines the vacuum would have its full effect in the turbine, which would mean more work being done and more economy. By using this low-pressure turbine in conjunction with the main engines some complications would arise, and it is a question whether for the increased economy the installation of the low-pressure turbine would be worth while. This combination is spoken of in Lieutenant Dinger's article in the "Journal of the American Society of Naval Engineers," November, 1908.

A good many foreign navies, in fact, nearly all, have tried, and are still trying, the installation of the turbine, but the results have been kept a secret and their economical and practical results are still a question of doubt. All reports, as a general rule, of the ships having turbine installation show a better economy at the maximum speed than the ships fitted with the reciprocating engine, but the results at lower speeds are not so well reported, and the average result is not very satisfactory for any authentic information.

Many things are claimed for the turbine, among them being

a saving in weight and a saving in space. The saving in weight *seldom* shows an advantage of 5 per cent. over that of the reciprocating engine. The tendency now is to increase the weight without any gain in economy. The turbines installed in the first battleship in the British Navy averaged about 40.4 pounds per I.H.P., now the average is about 43.2 pounds. When one takes into consideration that a turbine installation requires high vacuum, which means an increase in the cooling surface at the condensers and a more complete condensing apparatus, the weight of the turbine will not be so very much under that of a reciprocating engine for the same power. In order to get the greatest efficiency out of the propeller for general work, and at varying revolutions, the propeller must be increased in size. When this is done the speed of rotation of the shaft must be reduced. The general tendency is to decrease the revolutions, which, as a general rule, means increasing the diameter of the turbine rotor in order to obtain the proper vane speed. Any increase in the diameter of the rotor means, of course, an increase in weight and space. The average weight, including main-engine cylinders, shafting, main-engine framing and bearings, reciprocating parts of main engines, main-engine valve gear, main condensers, main air and circulating pumps, and propellers arranged for the *Louisiana, South Carolina, Michigan, Washington, Tennessee, West Virginia* and *Maryland* is 63.5 pounds per designed I.H.P. If we take out the main condensers, main air and circulating pumps and propellers, the average weight per designed I.H.P. will be 52.35 pounds. Should we take out the weight of the shafting aft from the engine this would bring the weight per I.H.P. still less. When one takes into consideration the turbine combinations that are being made to increase the economy and the increased diameter in the turbine it will not be astonishing to note that the weights will not differ much. There is not so much space saved in the turbine installation, and the space used by the turbine and condensers will not be much less than the space used for the installation of a reciprocating engine. The head room may be less in the turbine, but if proper facilities are made for removing the turbine casing

and removing the exhaust pipes the head room will not be reduced much. When the combinations of turbines are installed for economical purposes the space saved is very small, if any, over that occupied by the installation of a reciprocating engine.

Another one of the claims of the turbine might be added here, and that is the reduction in the engine-room staff. This is true, but if forced lubrication were used on the reciprocating engine (it is being installed on some at the present time), this engine-room staff might be reduced somewhat.

The adjustment of the rotors in a fore-and-aft direction should be very exact. When it is taken into consideration that the clearance is from 1/16-inch to 1/8-inch between the stationary blades and the rotor, it will readily be understood that there is not very much chance for a longitudinal movement of the shaft. When the turbine is going ahead and is suddenly thrown to full astern, there is bound to be a great strain set up in the thrust, which would, if there was the slightest give to the thrust, allow a play in a fore-and-aft direction. After running for a time the shaft collars are bound to wear the shoes in the thrust, and any slight play in the thrust will have to be closely watched. In case the shaft does change an amount equal to the clearance, it would mean that the shrouding of the blades would be badly cut, and in case the blades were not shrouded it might mean the destruction of the blades and the motive power of the ship. Cases have occurred where the shrouding has been cut, and in some cases where the blades have gone.

Nearly every ordinary case of breakdown in a reciprocating engine at sea can, with a little ingenuity on the part of the engineering personnel, be repaired and the ship be able to get to port. The parts of the reciprocating engine are easily accessible and can be temporarily repaired in some way or another. Spare parts can also be carried to cover any ordinary breakdown. It is different with a turbine: if any of the moving rotors are disabled there is no easy way to repair the defects unless the casing is taken off and proper facilities given to do the work, and if the blades are gone there is no way to repair

the defects. Ordinarily, most of the merchant ships now fitted with turbines run between two ports, and are at one time of the run close to the works where they were built or may be within easy reach of the works. With a man-of-war this is entirely different. She may be ordered at any time to any part of the world, and if easy and feasible methods of repairs are not given for the work then the ship should not be ordered to any place outside of close communication with the shops where she was built. No spares can easily be carried for the rotor of the turbine, and if this rotor should be disabled there is no easy method to repair it. A turbine ship might be on a foreign station for years at a time or might be on blockade duty or performing special duty in time of war. If anything should go wrong in the interior of the turbine, it is a much more difficult operation to repair it than with a reciprocating engine.

In accepting the turbine for naval purposes all the above points must be carefully considered to cover all conditions of speed and general work. The specifications for turbine ships should lay more stress on the economy to be obtained during service conditions than at full power, and any tests made with the turbine should be made with the installation *on board* and *under service conditions*. The comparison should then be made with the reciprocating engine. When the grand average shows a decided advantage in favor of the turbine for all around work for naval purposes over that of the reciprocating engine then, but not until then, should the turbine installation supersede the reciprocating engine in the ships which are to be built in the future, whose speed is not much above about 21 knots.

In writing this article I am not at all against the use of the turbine, but I think up to the present time it has not shown, taking everything into consideration, a great enough advantage in all-around work to warrant its taking the place of a reciprocating engine. I think that if more refinements were made on the reciprocating engine this form of motive power would, for naval purposes, keep at equal pace with the turbine installation.

NAVAL EXPERIENCES OF THE RUSSO-JAPANESE WAR.

Translated from the "Artilleristische Monatshefte" for January-February, 1907, by ALEXANDER EISENBERG, Translator of the Army War College.

THE EFFECT OF FIRE ON UNARMORED BROADSIDES.

These are well illustrated by reliable reports concerning the effects of Japanese shells on the unarmored parts of the cruiser *Askold* and battleship *Tsarevitch,* and are of great value, as they are the personal observations of naval officers who inspected these ships in the neutral ports to which they had escaped immediately after the battle of August 10, 1904.

Eye witnesses declare explicitly that the effects of the Japanese shells, after piercing the broadside, were usually very slight. Generally a thin steel partition was sufficient to isolate the results of bursting. Only in the cases of shots numbers 1 and 2 of the *Askold* were the second walls also pierced.

There are also similar data concerning other ships, although we have no detailed descriptions. One observer, for example, states with reference to the cruisers *Rossiya* and *Gromovoi,* which returned to Vladivostok after the battle of August 14, 1904, that he was surprised that these ships, having been under heavy fire for five hours, received damages that might look serious to the eyes of the layman, but which would never deceive a seaman as to their insignificance. The same remark applies to the injuries reported to have been observed on the *Orel.*

From these examples it has been concluded, first, that the Japanese fuses were very sensitive, and, second, that Shimose powder burned too quickly. The sensitiveness of the Japanese

These notes were published in the "Journal of the U. S. Artillery," and present discussions and views on naval material that should be of utmost interest to the Naval Service and to the Naval Engineering Profession.

fuses has been repeatedly spoken of by eye witnesses. The shells would burst almost instantly upon touching any object,

TABLE X.

A.—PROTECTED CRUISER *ASKOLD*.*

Shot No.	Caliber of projectile, cm.	Breach inflicted, sq. m.	Above or below water.	Effect on the broadsides.	Effects behind the broadsides.
1	30.5 or 20.3	Unknown.	Above.	Pierced.	Officers' cabin demolished. Several fragments broke a hole about ½ sq. m. in the rear wall of the cabin.
2	30.5 or 20.3	Unknown.	Above.	Pierced.	Two officers' cabins destroyed. In the midship wall a hole the size of a man. Fire started and two men killed.
3	20.3	½	Above.	Pierced.	Officers' cabin destroyed, but walls not pierced.
4	20.3	1	Above.	Pierced.	Effects of explosion slight.
5	20.3 or 15	¾	½ under water.	Pierced.	Burst in the storage room without further effect.
6	20.3 or 15	¾	At the water line.	Pierced.	Armored deck unharmed. Two compartments filled with water. Heeling very slight.
7	15	Unknown.	Above.	Pierced.	7.5 cm. of reserve ammunition set on fire. No further effects.
8	15	Unknown.	Near water line.	Pierced.	Armored deck unhurt. No effects of explosion.
9	15	½	do.	Pierced.	
10	15	Unknown.	do.	Pierced.	

B.—BATTLESHIP *TSAREVITCH*.†

1	30.5	0	2½ m. under water below armor belt.	Not pierced, the plates bent over a space 3½ m. wide.	No effects of explosion. About 150 tons of water poured in through the loosened parts.
2	30.5	2 x 2	Above.	Pierced.	None.
3	30.5	1 x 1	Above.	Pierced.	None.
4	20.3	5 x 1	Above.	Pierced.	Lining torn on the deck of the Admiral's office.
5	20.3	A round hole 1 m. in diameter.		Pierced.	Bakery destroyed. Various damages on deck.

* Taken from "Marine Rundschau," 1904, Vol. 10, and "Mitteilungen aus dem Gebiete des Seewesens," No. 11, 1904.

† Taken from "Marine Rundschau," 1904, Vol. 11.

however slight, and even the surface of the sea. While this is usually considered a great advantage, it was shown, however, that the quick burning of the Shimose powder was responsible in most cases for the shots causing damage of a local character only. It must also be remembered that the Japanese shells burst in many instances into 2,000 to 3,000 fragments, or even into dust. A statement by Dr. Wade, a physician of the Tshemulpo Hospital, reads as follows:

"A shell exploded on the conning bridge of the *Variag*. The effects were remarkable: one officer disappeared completely; of another only one arm was found; two men were badly wounded; most of the splinters were hardly as large as a pin-head. Therefore, the effects of the explosion were confined to a very small area, beyond which it caused very little damage. A sailor received from one of these shots 120 wounds in one of his legs; he soon recovered completely."

On the contrary, the effects of the Russian shells are said to have been of quite a different character. Nebogatoff explains in his report (letter of justification) that the Russian shells usually would bore only round holes the size of the caliber in the enemy's ships and failed to explode, or exploded too late. He himself saw such shots on the Japanese cruiser *Idzumo*. There is also a report that in an engagement of March 3, 1904, between three Japanese and six Russian torpedo vessels (at short range) the Russian shells would frequently pierce the hostile ships above the water line without causing further damage. Numerous similar shots had been reported in the Spanish-American naval war.

SHOTS ON SMOKE PIPES AND MASTS.

The effects of the Japanese fire on the smoke pipes and masts of the Russian ships again illustrated the sensitiveness of the fuses of the Japanese high-explosive shells. There is no record that projectiles striking a smokestack or a mast failed to explode; on the contrary, it has been repeatedly stated that the shells would detonate mostly at the point of impact, or at least at the rear surface of the part hit. There were also numerous

cases where the exploding shot would tear away the front wall without causing serious damage to the rear wall.

The damaged smoke pipes resulted mostly in considerably decreasing the speed of the vessel and in increasing the consumption of coal. Thus it is said that the *Tsarevitch* fell back after the battle at a speed of from 3 to 4 knots, and, instead of a daily consumption of 80 tons of coal, there was consumed 470 tons. Besides, smoke poured in great torrents along the deck and made impossible any operations in its vicinity.*

TABLE XI.

A.—SMOKE PIPES.

Vessel.	Shot.	Effects on—		
		Front wall.	Back wall.	Boiler.
Tsarevitch...	30.5 cm. high explosive shell.	Torn away from top to bottom.	None.	Fragments damaged several superheating pipes.
Tsarevitch...	do.	do.	None.	do.
Tsarevitch...	30.5 cm. shell with full point.	Pierced.	Torn.	None.
Askold.....	30.5 cm. shell.	Plates torn and bent.	None.	Smoke pipes clogged. Use of boiler stopped.
Askold.....	30.5 cm. shell.	The upper ¼ of the pipe completely cut off.	...	Fragments damaged seven water pipes.
Gromovoi....	Unknown.	Torn.	None.	Not noted.
Kniaz Suvaroff...	Unknown.	Both smoke pipes knock'd over.	...	Not noted.

In the discussions on the question whether the medium-caliber guns should be retained or discarded in the future, it was pointed out that this caliber had its *raison d'etre* as being the best means for demolishing the hostile smoke pipes. The loss of one or several smoke pipes may be compared to that of a sail on the old sailing ships, and such injury might prove

*It is this effect to smoke pipes that shows the necessity for armoring the pipes with medium armor to a height above the main deck. This armor will prevent smoke pouring into the vessel's living and battery spaces and will ensure a reasonable draft for the boilers.

sometimes of a decisive character in battle. The damage to the boilers on board the *Tsarevitch* and *Askold* has been attributed to the lack of armored gratings.

B.—MASTS.

According to "Marine Rundschau" (1904, Vol. II), the foot of the fore mast of the *Tsarevitch* was hit by a 30.5 shell. The part struck was torn almost completely away, and only in the rear there remained but a narrow connection between both bridges. One report states that this shot was a common shell

TABLE XII.

Vessel.	Turret armor.	Projectiles, kind and caliber.	Damage caused to turret.
Asama.....	20.3 cm.	Unknown.	Disabled by a hit; no further details.
Tsarevitch...	30.5	30.5 cm. shell.	Electrical apparatus disabled by concussion resulting from the explosion of the shell.
Mikasa.....	30.5	do.	Projectile exploded near the turret, disabling it temporarily.
Orel.....	15.	do.	Disabled at its base.
Orel.....	15.	do.	Disabled at its base.
Orel.....	15.	do.	Electrical ammunit'n hoist destr'd.
Borodino.....	30.5	2 heavy shells.	Turret completely disabled; 18 men killed.
Fujyama.....	30.5	30.5 cm. shell.	The lower part of the turret badly damaged.
Osliabia.....	30.5	Unknown.	Shell struck the port opening, exploded, pinned the gun in the position of the highest elevation and raised the top of the turret.
Kniaz Suvaroff...	30.5	Unknown.	Port hole hit; prepared ammunition exploded; gun crews killed; turret top raised and thrown to deck.

with delayed action fuse, on account of its far-reaching effects; while Galster, another writer, says that this result was produced by a high explosive (brisant) shell because of its high efficiency. Of other information concerning most hits only those are noteworthy where the total destruction of a mast is reported. On the Russian ships *Pobieda* and *Peresviet* both masts were shot away; on the *Kniaz Suvaroff*, one. The masts of the *Peresviet* were knocked over at a range of 7,000 meters.

INJURIES TO REVOLVING TURRETS.

Previous mention has been made of the disabling of gun turrets during this war, some permanently, and others only temporarily. In most cases either the turret top was bent inward or the auxiliary apparatus was damaged. No detailed accounts are on hand, however.

HITS ON GUNS AND THEIR MOUNTINGS.

A.—SHIELDS.

The gun shields proved efficacious, while, on the other hand, those ships that had unprotected guns suffered heavy losses both in men and material.

The shields of the *Askold* proved to be too short and narrow, although they resisted well the hostile fire. They had been extended down only to 0.3 meter above the deck, and the men were in a great number of cases wounded in the legs.

It is noteworthy that as one of the results of the experiences of the Russo-Japanese war, recommendations have been made to have the lighter guns (7.6 centimeter and smaller caliber)

TABLE XIII.

Ship.	Shields.	Injuries sustained.	Killed.	Wounded.	Complement.
Variag.....	No shield.	Nine of the twelve 15-cm. guns disabled in ½ hour. The ship was sunk by her crew.	40	62	535
Rurik.....	No shield.	All guns disabled, whereupon ship was sunk by her crew.	192	230	719
Rossia.....	No shield.	Seventeen of twenty heavy guns destroyed.	...	...	...
Aurora.....	No shield.	Shell hit the unprotected guns; pieces destroyed.	All cannoneers of the gun killed.		
Askold.....	Shilds 40 mm. thick.	All pieces remained undamag'd. The shields of the rear 15-cm. pieces had numerous evidences of having been struck; still none were pierced or noticeably bent.	11	15	576
Gromovoi..	Shields 30 mm.	None of the guns damaged.	None	None	...
Tsarevitch.	Shields.	None of the guns damaged.	12	50	778

arranged in armored batteries, as their ordinary shield protection has proved to be insufficient. Because these guns are used mostly for night work against torpedo craft, it is thought uneconomical to armor a special part of the ship for their protection, as armor would unnecessarily affect the water displacement. A suggestion has been made to place these pieces on disappearing carriages so that they could be kept beneath the armored deck during the day and raised to their proper places for the night.

B.—GUNS.

The following information has been gathered relative to injuries to the pieces themselves:

TABLE XIV.

Number.	Ship.	Make of gun.	Caliber.	Length.	Kind and cause of damage.
1	*Variag*.....	Canet.	15.	L/45	Gun partly demolished by shell.
2	*Askold*.....	Canet.	15.	L/45	About half of the barrels shot off; guns replaced in Port Arthur.
4-10	*Mikasa*.....	Armstrong wire wound.	30.5	L/40	Guns burst; muzzles shot away or damaged.
	Asahi.....				
	Shikishima..				
	Fuji.....				
11	*Orel*.....	Obuchow.	30.5	L/40	Gun burst; muzzle torn off at 18 m. from the muzzle. The fragment tore down the front wall of the bridge, crippling a 6-inch gun, and fell at a distance of 30 m. from its original position.

One investigator states that the bursting of guns on the Russian ships was mostly caused by Japanese shell fragments entering the bore. One case is cited where the gun burst, because, in course of loading, its shell was struck by such a fragment. The cases in the table referred to under Nos. 4–10 have been generally attributed to the weak construction of wire-wound barrels. The "Army and Navy Register" claims that these guns when tested before the war with smaller charges showed no faults. When, however, full charges were used in

the battle of August 10, 1904, the guns burst. The writer concludes that, had the Japanese used full charges in their peace practice, this fault would not have been discovered for the first time in the presence of the enemy. It is also said that the Japanese replaced during the war a part of their heavy wire-wound guns of English make by those of other designs.

C.—AMMUNITION.

Reports of premature explosion in many cases of ammunition stored near the guns proved such disposition to have been a fatal mistake. For example, on the *Kniaz Suvaroff* the ammunition in one of the turrets was exploded by a shot through a port hole, and resulted in killing a number of the men in the turret, wounding the rest of them and raising the turret cover. On the *Variag* a similar hit resulted in a considerable conflagration; several men were instantly killed and one fell into the elevator shaft, his clothes ablaze.

On the other hand, according to statements of the officers of the *Askold,* the ammunition does not necessarily involve danger. An uncovered 15-centimeter cartridge case caught fire and burned out with a hissing flame, without injuring the ammunition carrier.

D.—MISCELLANEOUS.

There were many cases of the crippling of lighter guns. On board the *Variag,* for example, a 7.6-centimeter gun was thrown to the rear across the whole width of the deck. The officers of the *Askold* reported that damage was frequently caused to the heavy guns of that ship through the recoil cylinders being struck by shell splinters. No further details, however, are given. There is no definite information that sights were damaged by shell splinters, but they were frequently disabled by shots striking short and covering them with salt water.

THE EFFECTS OF CONFLAGRATION AND GASES.

According to the unanimous statement of numerous reports, the conflagrations caused by the Japanese shells on the Russian

ships, as well as the poisonous gases produced by the high explosive, contributed conspicuously to the success of the Japanese.

Rozhdestvensky reported as follows: "The most dreadful enemy of the battleship is the fire created by the ceaseless explosion of shots. There was little wood on our ships, but the very paint would take fire and wrap the ships with a sheet of flame."

On the *Variag* there were five simultaneous conflagrations in different parts of the ship; on the *Rossia* eight men were burned to death, and the *Orel* is reported to have been set on fire 34 times in the battle at Tsu-shima. In that battle the Russian ships were at times so wrapped in smoke that they entirely disappeared from the sight of the Japanese. The conflagration on the *Borodino* was particularly fatal. Fire reached the magazines and caused an explosion, and the ship sank so fast that but few men could escape. Other observers, however, attribute this explosion to the work of a torpedo boat.

Rozhdestvensky's assertion that the paint of the ships had much to do with the rapid spreading of conflagration is also confirmed by other reports. It has been clearly proved that with every hit by a shell against the armor plate a shower of burning particles of paint would be thrown out in all directions, and would frequently wound the members of the crew. But it seems that only the outside paint would take fire while the red lead beneath would remain undisturbed. Contrary to Rozhdestvensky's statement, Nebogatoff claimed in his report (letter of justification) that there was much wood on the Russian ships and the coal stored on deck also took fire. The teakwood decks seem to have resisted the fire successfully. The upper deck of the *Tsarevitch* was pierced by a 30.5-centimeter shell and the teakwood covering was torn over an area 2 x 2 meters, but not set on fire. Also, on the *Orel* the teakwood planking of the upper deck was completely torn off and split, but no traces of conflagration were visible.

The poisonous effects of the gases from the Shimose powder used by the Japanese were shown very frequently. The follow-

ing is from the reports on the battle of August 10, 1904: "Twenty-four hours after the battle many of the men were still complaining of deafness, dizziness, loss of memory and headache, although they were not wounded. The hair and beards, and sometimes even the skin, of those who were in the near vicinity of an exploding shell turned a deep yellow. The same discoloring was found also on the parts of the ship at the points of explosion."

As a result of the gases from a shell on the *Tsarevitch* two men were suffocated. According to Admiral Nebogatoff, on board the *Sissoi Veliky* two of the surgeons were suffocated by similar poisonous gases. On the other hand, in contrast with the effect of the gases, the shell splinters proved to be quite aseptic after penetration in the human body, and this is believed to have been the result of the high temperature developed in the exploding projectile.

Especially worthy of note are the instances where smoke and gases penetrating the gun turrets or conning towers compelled the men to abandon their posts. Lorenzo d'Adda states that a thorough examination of the *Orel* in Maizurn showed that most of the gun turrets stood undamaged among heaps of ruins, but that, according to the testimony of the officers, they had been abandoned by the men to avoid suffocation. It is reported of the same ship that smoke pouring from the hammocks and ropes near the conning tower on four occasions compelled the men to abandon their posts. Smoke penetrating through the skylights into the firerooms drove out the men. Again, smoke passing through a 15-centimeter turret entered the lower decks. The men below, thinking that an explosion had occurred in the turret, started to flood the magazine, when the commanding officer, discovering the cause of the trouble, prevented them.

In conclusion, we call attention to what Admiral Nebogatoff has stated in reference to the situation on board the *Kniaz Suwaroff*, where the entire armament was crippled because of the heat of the conflagration. The Russian shells, on the contrary, did not cause fire and developed only harmless gases.

Nebogatoff claims that pyrotilin was used as an explosive; and although years before it had been decided to introduce melinite, or some other high explosive, this had not been done up to the time of the war.

THE EFFECTS OF HIGH ANGLE FIRE.

Having captured 203-Metre Hill, dominating the city and port of Port Arthur, the Japanese established there 28-centimeter howitzers and opened fire on the Russian ships anchored in the port. This firing lasted from the 2d to the 12th of December, 1904. The first reports of this bombardment claimed that the fire was most efficient and that it succeeded in sinking the hostile ships one by one. But when the sunken ships were examined by divers, after the fall of the fortress, it was shown, to the general surprise, that the Japanese fire had inflicted very little damage to the ships, which, in reality, were sunk by the Russians themselves with torpedoes and mines. The majority of the Japanese shells failed to explode. An official report of the Japanese on December 7th stated that the Russian ships had been hit up to that day at least 134 times. Taking this number as an average for the remaining time from the 7th to the 12th of December, the total of the hits would amount to 268. But the upper decks of the ships showed only the following breaches, caused by the 28-centimeter pieces: The *Peresviet,* 12; *Pobieda,* 4; *Poltava,* 3; *Pallada,* 7; and *Bayan,* 3. Although the damage to the *Retvisan* could not be accurately determined, those portions visible above water failed to show any traces of hits.

The damage caused by these hits was also considerably less than was to be expected. In most cases the energy of the projectiles after piercing the upper and main decks had been so reduced that they could not penetrate the armored deck. For example, the battleship *Peresviet,* range 6,440 meters, projectile 28-centimeter shells; angle of fall 30 degrees; thickness of armored deck plate 32 to 38 millimeters plus 15 to 25 millimeters sheathing.

TABLE XV.

Deck.	Number of hits.	Number perforating.
Upper	12	11
Main	11	6
Armored	6	4

These shells were found not to have exploded. Those shells which exploded on the armored deck produced only slight bending; those which pierced that deck caused but little damage below. The structure of the *Peresviet* had not suffered at all from this fire.

These data are the more remarkable as the angle of fall was relatively very favorable. Some explanation is to be found in the fact that the Russians had covered their decks with thick layers of coal in bags, and that the Japanese shells were too light. Their weight was only 217 kilograms, and had black powder bursting charges of but 8 kilograms.

"Nauticus" remarks that although these facts are not sufficient to prove the ineffectiveness of high angle fire, still they show that this fire should not be overestimated. It seems true also that howitzers are of less value than direct-fire guns, but not to such an extent as to entirely explain the proven superiority of flat-trajectory fire upon a ship as a target.

THE EFFECTS OF NAVAL ARTILLERY ON COAST FORTIFICATIONS.

The Japanese assiduously bombarded the fortifications of Port Arthur and Vladivostok, but with little success. The first attack of February 9, 1904, against the forts provided with thirty-two 15 and 10-centimeter guns proved their superiority to the Japanese naval artillery, and Togo failed to approach close to these fortifications. A similar failure occurred on July 26, 1904. On this day a combined attack of both the Japanese army and navy was determined on; but the forts again compelled Togo to withdraw.

The following details are of especial interest: The cannonade lasted usually for an hour and was conducted at a range of from 8,000 to 9,000 meters. On March 10, 1904, the Japanese fleet fired about 155 heavy shells, resulting on the Russian side in

nine men killed and five wounded. On March 22d, 100 similar shots caused the killing of five men and wounding of nine; 185 shots on April 14 wounded five Russians. As to the effects of the fire upon the fortifications themselves the shells that exploded on the ground or against stonework produced but very insignificant craters. Brick walls were not injured even when the shells exploded in the immediate neighborhood. One shell exploded in the concrete parapet, tore off part of the outer layer and cracked the inner surface, but did not perforate the wall. The result of the bombardment was "more than a failure." It may also be mentioned that the Japanese occasionally used high angle fire against Port Arthur, but this resulted in the gun carriages being badly damaged because of the great elevation. They had probably not been constructed with a view to such use.

FAILURES OF SHELL TO EXPLODE.

This condition was common to both sides, but with the Japanese only at the beginning of the war; while on the Russian side these failures are said to have largely influenced the unfortunate result of the war. Although during the first attack on Port Arthur, February 9, 1904, and on Vladivostok, March 6, 1904, almost 50 per cent of the Japanese shells (lyddite) failed to explode, yet in the bombardment of Port Arthur, March 10, 1904, all shells exploded. This improvement coincides in date with the introduction of Shimose powder in the Japanese navy. The Japanese army, on the other hand, never used Shimose powder, and this, it is stated by many reports, was the cause of numerous failures to burst during the high angle firing from land upon the Russian ships in the harbor of Port Arthur.

Frequent failures of the Russian shells (even as high as 66 per cent) were confirmed even by Rozhdestvensky and Nebogatoff themselves. The "Novoye Vremya," discussing this circumstance in a lengthy article based on numerous reports, proved that the number of hits by the Russian guns was considerable, but these hits mostly resulted in piercing the enemy's ships, producing a breach equal to the diameter of the

shell, and without exploding. Therefore, the fault of the failure of the Russian fleet was in the first place laid at the door of the Government. It was also pointed out that Rozhdestvensky's ammunition might have deteriorated during the long passage through tropical regions.

CONSUMPTION OF AMMUNITION.

We have but very little information as to the consumption of ammunition in the different naval engagements.

TABLE XVI.

Vessel.	Period of fire.	Number of shots per gun—			
		30.5 cm.	20.3 cm., older pieces.	15 cm.	7.5 cm.
Variag.....	50 minutes.	...	...	30	60
Koreyetz.....	50 minutes.	...	23	18	...
Tsarevitch.....	2½ hours.	30	...	50	...
Askold...	1½ to 2 hours.	...	...	20	25

There is an interesting report that, in the battle of August 10, 1904, the Japanese had consumed all their ammunition and, therefore, could not complete their victory nor prevent the Russian ships from returning to Port Arthur or escaping to neutral ports.

TRAINING OF THE COMBATANTS IN FIRE CONTROL.

The Japanese seem to have been better trained in fire control than the Russians, and this was repeatedly recognized by the latter themselves. A good illustration of this was the firing upon the *Tsarevitch* in the battle of August 10, 1904. Most of the shots struck the conning tower and the adjacent upper works. The gunners had been instructed to aim particularly at those parts of the ship. Forty per cent of the fifteen 30.5-centimeter shots hit close to the conning tower over a surface representing but 20 per cent of the whole. It is also remarkable that in many instances the shots struck the upper parts

of the ship just above the water line and at half a foot below the upper deck. This can be explained by the fact that the masts, smoke pipes and other prominent parts drew the attention of the gunners. This may also partly explain the fact as already stated that most of the armor belts remained undamaged.

According to Captain Akiyama's statement, the Russians averaged less than one hit to every ten shots, while the Japanese hit at least four times out of ten. In the battle of Tsu-Shima, Togo's flagship, the *Mikasa,* was hit only four times, although Rozhdestvensky had ordered a concentration of fire upon her. A British captain is reported to have been standing on the upper deck of this ship the entire time and remained unhurt; also Togo was not wounded, although he stood quietly on the upper conning-tower bridge. The superiority of fire action of the Japanese appeared in these two essential points:

1. The use of telescopic sights.
2. An excellent system of range finding and control of fire.

The Port Arthur fleet had no telescopes at all, and Rozhdestvensky's fleet was provided with these instruments only just before leaving Europe. The old guns were provided with telescopic sights of the Perepelkin system, and the newer pieces with Krilov's. The gunners were taught during the voyage to handle these instruments. As to the range-finding apparatus, the officers claim that they would generally not admit of measuring distances of from 7,000 to 8,000 meters, and such ranges had to be estimated.

When Rozhdestvensky's fleet was still before Madagascar, target practice was held. Ranges were taken by the several ships on one of the cruisers detailed as a target for range finding. The range finders on one ship showed a distance of 7,300 meters, while that of another ship marked 11,000 meters, but nothing was done to correct these faults of the instruments or to adjust them. Nebogatoff states that before this the Russian navy had used a range finder of the Joly and Mikasev system, and only at the last moment, before the departure of the squadron, apparatus of the Barr and Stroud system had

been installed on the ships, and as a natural result no one had sufficient experience to handle them skillfully. The number of these instruments was also insufficient. There were but two to three to a ship, while the Japanese had one for each gun.

How insufficiently drilled the Russians had been can be understood from the repeatedly stated fact that the heavy pieces of the *Tsarevitch* fired their first shots in the battle of February 9, 1904. Finally, it must be remembered that Nebogatoff himself partly attributed the unsuccessful firing of the Russians in the battle of Tsu-Shima to the inequality of the artillery and ammunition, as well as to the ships themselves. We quote the following from Nebogatoff's "Letter of Justification": "His ships were provided with obsolete guns. The 15-centimeter pieces averaged one shot per minute, while the corresponding Japanese guns could fire from four to six times per minute, at least. The unfavorable arrangement of the Russian guns and the construction of the gun ports did not permit of taking advantage of all the most favorable ranges and angles. Toward the end of the battle, the Japanese fired upon the Russians at a range of from 9,500 to 10,500 meters, while the Russian guns could not reach beyond 9,200 meters." These circumstances were the most important influences which decided Nebogatoff to surrender his ships.

A part of the Russian ships had been furnished with new guns just before the departure, but the gun ports had not been altered, and, as it appeared later, this did not allow the guns sufficient angles of elevation for extreme range finding. The speed of the ships was also insufficient. The *Nicolai I* could not show more than 11.2 knots at the utmost power of all her boilers and engines. The faulty rigging of the cruiser *Vladimir Monomakh* caused such heavy rolling that the accuracy of fire was considerably decreased.

PSYCHOLOGICAL EFFECTS OF FIRE.

The moral effects of artillery fire on the crews were probably as instrumental in the outcome of the several naval engagements as the material results, if not more. Up to the time

when the Russians, at the battle of August 10, 1904, had given up their attempt to break through the Japanese lines toward Vladivostok and thus declared themselves beaten, there really was no serious advantage on the Japanese side. The losses in ships and men were about equal, and perhaps even greater among the Japanese; and, furthermore, the Japanese had run short of ammunition toward the end of the battle. Therefore, we must admit that the victory of the Japanese was due more to the general low spirits of the Russian forces than to the material results.

It was the same in the battle of Tsu-Shima. Rozhdestvensky declares: "For the first half hour our men fought excellently. They really possessed more experience and skill than had been supposed. All the losses to the Japanese were inflicted during this time. But soon our men became demoralized by the Japanese fire, and then everything was over."

It is interesting to discover what purely artillery means caused this sudden moral breakdown of the Russians. The answer is to be looked for in the rapid and efficient firing, with numerous, well-aimed and well-located hits that spread their gases and fragments into every loophole of the conning towers and entered every port hole, covering the enemy with clouds of smoke, flames and flying particles of metal. The moral effects of single, separated shots will never be as considerable as those of rapid fire, and from this viewpoint a *total elimination of the medium-caliber artillery from the battleships of the future cannot be justified.*

PART II.

THE DEVELOPMENT OF SHIPS' ARMAMENTS IN DIFFERENT COUNTRIES SINCE THE WAR.

INTRODUCTION.

In the first part of the present work we have presented certain information gathered from the theater of the war referring to the character of the naval artillery and its effects on vessels and on their different parts. In this part of the work we intend to show what conclusions have been drawn from those experi-

ences and *how they influenced the armament of the lately constructed battleships and armored cruisers.*

The armament of recent years has a pronounced tendency toward increasing the caliber. This is the second step in this direction since the time of the final discontinuance of muzzle-loading guns and the introduction of the breech loader. The first movement toward increasing the caliber of the guns had reached its climax in 1880–1885, with guns of 41.3 centimeters (England), 42 centimeters (France), and 43 centimeters (Italy). Then followed a movement backward to 37 and 34 centimeters, until, in 1893, the 30.5-centimeter gun had been everywhere pronounced as the largest gun admissible for battleships. The present, second, step toward increasing the caliber began a few years before the Russo-Japanese war. It was first shown in the increase of the caliber of the medium artillery in Italy, namely, on the ships *Regina Margherita* and *Benedetto Brin,* launched in 1901. While the average caliber of the medium armament of that time was 15–16.5 centimeters, these ships received, besides our 0.5-centimeter guns, medium armament of four 20.3-centimeter guns and twelve 15-centimeter. After that time almost all other fleets began to demand a larger caliber, which involved the suggestion to discontinue the medium artillery altogether and supply their places by a larger number of heavier guns. Simultaneously a tendency was developed to improve the power of different guns by increasing the length of the bore.

Although this movement had thus arisen before the war in the Far East, the latter had a great influence on the furtherance of this movement, and almost all discussions of this question refer to and are based on the events and experiences of this war.

A résumé of these discussions is the object of the present work, and, for the sake of consistency and chronological order, we will also touch upon those events which characterize the beginning of this movement before the war. But, first of all, it is necessary to define the term "medium artillery." Generally this name is applied to guns of from 10 to 20 centimeters cali-

ber, while a gun over 20 centimeters caliber is regarded as "heavy." The reason for this discrimination is based on the fact that a gun not exceeding 20 centimeters caliber can be laid by hand, while heavier calibers require mechanical assistance. But as a gun laid by hand possesses a greater rapidity of fire than that moved and directed by machinery, the gun under 20 centimeters caliber also differs from the heavier ones by its tactical applicability. Further, these guns differ also as to the manner of their installation on the ship: the medium-caliber guns (under 20 centimeters) are better arranged in casemates, while the heavier guns are placed preferably in single or double turrets, because the more sensitive mechanism of the heavier guns requires a better armor protection than the simple construction of the lighter pieces.

According to this principle, the establishment of smaller guns (under 20 centimeters) on a barbette turret carriage is regarded as erroneous from many standpoints, for the increased weight of the parts to be moved compels the application of machinery, although not required by the character of the gun itself.

E. Descowitch presents the following numerical illustration:

Austrian 19-meter guns; L/42 *von Skoda.*

Arrangement.	Casemates, tons.	Single turrets, tons.
Weight of the barrel,	12.3	12.3
Weight of the carriage,	10.49	20.37
Weight of the platform,	0.98	2.92
Weight of protective shield,	5.84	....
Weight of movable armor,	....	28.7
Totals,	29.61	64.29

The weight had thus doubled as a result of placing the gun in an armored turret. The only advantage is a greater arc of fire, but this gun is not equivalent to that which might have been obtained by placing two guns in the turret instead of one.

The latest development of the German ships also illustrates this view. While ships of the *Kaiser* type have six out of eighteen 15-centimeter guns in single turrets, the ships of the

Wittelsbach type, having the same number of guns, have only four single turrets for the 15-centimeter caliber. In the battleships of the *Deutschland* type the turret arrangement for the medium artillery has disappeared altogether, and all 17-centimeter guns are placed in single casemates.

In this work we will always consider the 20-centimeter gun as the upper limit of the medium calibers, so that, for example, an armament of four 30.5-centimeter and twelve 24-centimeter calibers, all placed in double turrets, will be regarded as a total exclusion of the medium artillery, although there is a provision for lighter guns designed to engage torpedo boats.

It is now known that most of the maritime powers have decided to eliminate the medium artillery. We shall first inquire into this and afterwards mention a series of opposed teachings urging the retention of certain medium-caliber armament. Germany must be left out altogether in this review, as no reliable data have been published concerning the equipment of the newest battleships *Ersatz Bayern* and *Ersatz Saxonia.*

THE DISCONTINUANCE OF THE MEDIUM CALIBERS.

1—ENGLAND.

A. The Proposition of Cuniberti.—The Armament of the New Battleship.

It has been stated that the movement toward an increase of the caliber and final discontinuance of medium guns began with the construction of the Italian ships *Regina Margherita* and *Benedetto Brin.* The second step in this direction was also made in Italy with the *Regina Elena,* launched in 1904, and designed by Cuniberti, Chief Constructor of the Italian Navy. It had a displacement of 12,600 tons and the following armament: Two 30.5-centimeter guns of 40 calibers, twelve 20-centimeter guns and twelve 7.5-centimeter guns of 45 calibers. The essential feature of this equipment was that all the 20-centimeter guns on this ship were placed in double turrets, while on the *Regina Margherita* they were mounted in single casemates. In opposition to the arrangement in double turrets, it was pointed out that, light calibered as they were, this

would change the character of the medium artillery, and that it would be better, therefore, to discontinue that kind of ship armament altogether and to supplant them with fewer but heavier guns.

Cuniberti himself recognized this, evidently, for even in 1903 he published in "All the World's Fighting Ships—Jane," under the title: "An Ideal Battleship for the British Fleet," a sketch of a battleship equipped exclusively with heavy artillery and carrying light artillery only for action against torpedo boats. It was to have a displacement of 17,000 tons and the following armament: Twelve 30.5-centimeter guns in four double and four single turrets, twelve 7.6-centimeter and several machine guns.

Cuniberti starts from the premise that the artillery of the future must fight at extreme ranges, where the accuracy of fire cannot be relied upon and the penetrating power of the shot is considerably reduced. Under such conditions, the medium calibers would be quite useless. Furthermore, the decreased accuracy of fire would lead to a waste of ammunition, and this could be avoided only through the increase in number of the heavy armament. Thus the ideal ship would have a decisive effect at great ranges; yet this ship would be powerful also in a fight at close quarters against a ship largely equipped with medium artillery, for her armor being much heavier (30.5 millimeters) in accordance with her heavy artillery, she would be able to approach near to the enemy without danger and destroy him with superior fire.

The Russo-Japanese war has given many proofs of the correctness of Cuniberti's views, especially in reference to the effect of fire at great distances, as no heavy armor was pierced in that war.

The newer English battleships have almost fully embodied Cuniberti's ideas and advice. In the ships of the *King Edward* type we see for the first time two kinds of heavy-caliber armament, together with a medium artillery equipment. The *Lord Nelson* type has two kinds of heavy guns, but no medium artillery. And, finally, the *Dreadnought* has adopted the idea

of heavy artillery of one kind only. In the last named is found a complete fulfillment of the ideas of the Ideal Ship application. Here is the equipment of these ships:

Type of ship.	Launched.	Displacement.	Number of guns, cal. cm. 30.5	23.4	15.0	7.6
King Edward,	1903	16,350 tons.	4	4	10	14
Lord Nelson,	1906	16,500 tons.	4	10	—	15
Dreadnought,	1906	18,000 tons.	10	—	—	27

In another article published in "All the World's Fighting Ships," 1906–7, Cuniberti goes still further and proposes an armament of eight 40.6-centimeter guns, arranged in the shape of a rhombus. This disposition enables firing ahead or astern from six guns at once, and from all eight when firing from broadside. In this second study Cuniberti insists upon the gun being able to penetrate the heaviest armor at a range of 10,000 meters and with a striking energy such that a single hit would disable the enemy's ship and put it out of action. The distance of 10,000 meters has been assumed because of the increased radius of action of submarine boats of the future. The 30.5-centimeter guns cannot serve this purpose, as has been proved on the battleship *Tsarevitch;* this ship was struck by many 30.5-centimeter projectiles without being seriously damaged. Consequently the 30.5-centimeter must give place to a heavier gun.

Cuniberti enumerates additional requirements for the ship of the future: A complete armor protection of the whole ship, both above and below water; the use of turbines; numerous small and light boilers; the storage of ammunition in numerous, possibly small, magazines scattered over the whole ship, etc. Cuniberti admits, however, that such a ship would require a large displacement, so that in the meanwhile we must be satisfied with a caliber smaller than the proposed 40.5 centimeters.

It was reported recently in the English press that the new armored cruisers of the *Invincible* type will receive eight 30.5-centimeter guns, arranged in the rhombus shape indicated by Cuniberti in his second article. The displacements of these ships will be about 17,500 tons.

B. The Equipment of the Future English Battleships with 13.5-inch Guns.

It has not been possible as yet to obtain accurate information of the equipment of the new English battleships. It seems that the three latest ships, of 1906–7, will have a greater displacement (about 18,500 tons), but the same equipment as the *Dreadnought*. On the other hand, there is some information that England is again considering the adoption of the 30.5-centimeter caliber, or that she will probably select the 34.3-centimeter (13½-inch) L/45, for the main armament. This caliber had been introduced previously into the English navy, but had a length of 30 calibers. It still exists on some of the older battleships, *i.e.*, on the *Royal Sovereign* type, launched in 1891–2.

In recommending the introduction of the larger caliber, the "Naval and Military Record," of September 13, 1906, argues that as other countries are proposing to build ships of the *Dreadnought* type, the British authorities must decide whether the 30.5-centimeter caliber should have a further development or whether it is necessary to pass to a higher caliber at once.

The further development of the 30.5-centimeter gun is possible only in the increase of the length of the barrel beyond 45 calibers. But there are obstacles dependent on the weakness of the wire-wound construction. In consideration of the faults displayed by the wire-wound guns of the *Majestic*, it would not be wise to risk the consequences that might follow the increase of the length of the barrel beyond that of the *Dreadnought* type, and beyond 45 calibers. Therefore it is probable that England will adopt the 34.3-centimeter gun. The fact that Germany, as lately reported, purposed to equip her new battleships with 28-centimeter guns of 50 calibers length of barrel, should not influence England to limit her improvement of the artillery to a similar increase in gun length. In conclusion, this magazine recommends the following equipment of the new battleships:

Four 34.3-centimeter guns at bow and stern.

Six to eight 30.5-centimeter guns on broadside.

C. Training in Long Range Firing.—New Apparatus for Fire Direction.

While formerly the main stress was laid upon the rapidity of fire, as a result of the experiences of the Russo-Japanese war the British Admiralty has ordered the training of the Navy in firing at extreme ranges. At the yearly "battle practice," the target, according to the caliber of the firing gun, is fixed at a distance of 4,500–6,500 meters. The target is a rectangle 27.4 by 9.14 meters, and closely corresponds in size to the middle portion of a battleship which covers the engines and the boilers.

Attention is paid also to increasing the accuracy of fire by improvements in devices for range finding and fire direction. The fighting tops of all ships will be removed and replaced by *firing stations*. The ranges are measured at the station and the sighting of the gun is fixed from there by means of an apparatus based on the application of synchronous electro motors. The speed of the ship and her deviations from a course are eliminated. So far there are known to exist in the British Navy four different systems of such apparatus, namely, Barr and Stroud, Siemens, Vickers-Maxim, and Vyvyav-Newitt. The details of these systems have not been published.

2.—FRANCE.

The debates in the Chamber of Deputies on the budget of the Navy were conducted entirely under the title of "War Experiences." The Maritime Ministry, through the "Higher Council of the Navy," demanded six battleships (*Danton* type), displacement 18,000 tons, a speed 19 knots, with the following armament: Four 30.5-centimeter guns, twelve 24-centimeter guns, sixteen 7.5-centimeter guns, and eight 4.7-centimeter guns.

Although there was some opposition to this armament, and some other propositions were made in this regard, the budget has been approved without modification and the immediate construction of six ships decided upon. We give below the part of the debates most important to the question of armament:

A. The Report of Deputy Charles Bos.

This report may be summed up as follows:

1. The fighting distances have increased from 3,000 meters to 6,000 meters.

2. The medium calibers are not efficient at a distance of from 6,000 to 7,000 meters, and are, therefore, useless on battleships.

Bos states that a projectile should perforate, at a distance of 6,000 meters, a cemented armor plate equal in thickness to the caliber of the projectile. Reviewing the French Navy artillery, he asserts that there was not a single gun that could meet this requirement. The smallest caliber that can meet this demand is the 24 centimeters, while the 19.4-centimeter guns cannot serve this purpose.

3. The heavy artillery should be represented by but one type; whereas in the French depots, ports, and on ships one meets a great variety of guns such as 42, 37, 34, 30.5, 27.4, 24, 19.4, 16.4, 13.8, 10, 6.5, 4.7 and 3.7-centimeter, and each of these calibers has various models.

The uniformity of caliber has the advantage of an easier replenishment of ammunition and permits a better training of the men. The heavy guns should be placed exclusively in double turrets.

4. Of the heavy artillery, the 27.4-centimeter L/45 is preferable, as the 30.5-centimeter is, in Bos's opinion, too heavy, and the 24-centimeter too light. The middle type of 27.4-centimeter, model 1902, can advantageously replace the 30.5-centimeter type.

5. The lighter guns for use against torpedo boats must be increased to 7.5-centimeter caliber, while at present the highest caliber of these guns in existence in France is 6.5 centimeters, which, Bos considers not sufficiently strong. Further, he recommends that the lighter calibers be placed in protected batteries.

6. A uniform projectile is also required, namely, a steel-capped shell with a high explosive charge. The cast-iron shells

and black powder (even in steel shells) is ineffective against modern armor.

7. Guns of the same caliber should, as a rule, have identical carriages, so as to be interchangeable.

8. On account of the increased fighting ranges, all guns must be provided with telescopic sights. The men should be thoroughly trained in firing at great ranges of from 6,000 to 8,000 meters; the apparatus for measuring ranges should be improved.

9. The firing exercises should be conducted with actual service and not reduced charges, as heretofore, and with greater frequency. For this purpose a larger supply of ammunition should be provided.

10. The ammunition supply of the ships and the reserve at the ports should be increased. The Russo-Japanese war has taught that the consumption of ammunition in battle is exceedingly high; in the action of August 10, 1904, for example, Togo could not obtain full results of his victory because he had run short of ammunition for the heavy guns.

As the French 30.5-centimeter guns are provided with only sixty shots, twenty of which are armor-piercing shells, and as, in that war, four shots were fired in five minutes, the supply of a ship would last but twenty-five minutes.

11. The ironclad cruisers also should be equipped with uniform heavy artillery, as otherwise they are defenseless against battleships, and therefore useless. At present, Bos states, all the French armored cruisers, beginning with the *Dupuy-du-Lome,* launched in 1890, and down to the *Jeanne d'Arc,* launched in 1899, are too weak in armament, as their largest caliber is 19.4-centimeter, and the average only 16.4 or 13.8-centimeter, or even 10-centimeter guns. Therefore the Navy Department is right in deciding to increase the armament of the new armored cruisers *Edgard Quinet* and *Waldeck-Rousseau,* namely, from four 19.4-centimeter and sixteen 16.5-centimeter guns to fourteen 19.4-centimeter.

He recommends to move a step further in this direction and to equip them with 24-centimeter guns only, even if a smaller

number must be installed. Even the smallest cruisers should not carry any caliber under 15 centimeters as their main armament.

12. The fleet should consist of battleships of one type, according to the principle—one type of ships, one type of guns, and one type of projectiles. Bos recommends the following "Ideal Type";

Displacement, 18,000 tons.

Armament, sixteen 27.4-centimeter guns in double turrets; twelve 7.5-centimeter guns in protected batteries; twelve 4.7-centimeter guns in protected batteries.

B. The Proposition of the Ministry of Naval Affairs.

The equipment as proposed by the Navy Department was accepted finally by the Chamber of Deputies.

The speech of Mr. Thomson, Minister of Naval Affairs, touched upon the following questions:

1. Question of the Caliber.

In order to defend the proposition to employ a secondary equipment of twelve 24-centimeter, together with the main armament of four 30.5-centimeter guns, Thomson refers to the battle of Tsu-Shima. In this battle, he declares, that which was most effective was the shower of fire with which the Japanese met the enemy at the very beginning, and which led to the destruction of the Russian ships. Therefore, it is necessary to equip the battleships with the most rapid-firing guns, and at the same time of such power that they could pierce an armor plate a caliber thick, at a distance of from 6,000 to 7,000 meters. The new 24-centimeter gun serves this purpose marvelously.

At a range of 6,000 meters and at an angle of impact of 30 degrees it can perforate a plate 265 millimeters thick, and at the same time a rapidity of three shots a minute can be attained. As the English and French 30.5-centimeter guns can fire but two shots a minute, the superiority of the new 24-centimeter gun in its rate of fire is quite obvious. The minister stated explicitly that the new model was no longer a project but a completed instrument whose tests had proved it to be successful.

2. The Question of the Projectile.

The increase of the fighting ranges has for its necessary result the modification of the projectile also.

The Russo-Japanese war has proved that the armored vessels probably suffered less from the piercing of their heavy armor plates than from the devastation caused by the splinters of the shells. Not a single Russian ship, even in the battle of Tsu-Chima, had its heavy armor actually perforated. In order to prevent a battleship from capsizing because of perforations near the water line, it has been designed, during the last ten years, to give those parts above the water line a comparatively thin armor plate. Now, for action against this reduced thickness, a shell has been invented whose walls are strong enough to break through this thin part, but which is capable of carrying a high explosive charge. The question then arose whether the different projectiles could not be replaced altogether by this shell. But this change cannot be accomplished in a day, for, in addition to the projectiles below 16.5-centimeter caliber, there are still on hand 196,000 projectiles, one-quarter of which, at least, consist of cast-iron shells.

However, it has been decided to provide the large armored ships planned for 1900 with steel shells only, and also to replace in the other ships as far as possible all cast-iron shells by those of steel.

The French naval ordnance bureau has striven in the last years to increase the muzzle velocity. The results reached have been apparently successful, and the future improvements of powder will be utilized to increase the weight of the projectiles only.

3. Target Practice with Service Charges.

To learn to fire at extreme ranges, we have replaced the practice ammunition hitherto used by service ammunition, and without any harm to the guns. The question of strain on the gun had to be considered in this connection. The experiments in Gavres have set all doubts at rest. Practice will be conducted at distances of 4,000, 5,000 and 6,000 meters, instead of

at from 2,000 to 3,000 meters. This change will cost about three millions; but it will give us an opportunity to make better use of our ammunition than heretofore. Ammunition long in storage deteriorates and requires to be remanufactured. This will be avoided hereafter.

4. Telescopic Sights and Fire Control Apparatus.

We have been working for the last ten years to replace the ordinary open sight by optical apparatus. The value of the telescope is still uncertain, and we are endeavoring to get something better. It was thought necessary to try to fit the present telescopes on the guns of the large ships. The test is going on now, and if new and better glasses are invented it will be easy enough to replace the old type without changing the mounting on the gun.

As to fire control, we were the first to concentrate the firing in the hands of special officers and to provide ships with apparatus for immediate communication of the orders for firing.

The ship *Couronne,* hitherto used as a training ship, is not fitted with this new system, and, therefore, the cruiser *Pothuan* has been designated for this purpose.

C. Lockroy's Proposition.

Mr. Lockroy (formerly Minister of the Navy) published a series of articles in "Le Temps" in regard to artillery questions. He recommends the following type of battleship:

Displacement, 18,000 tons.

Artillery, twenty 24-centimeter guns, several light guns.

He made the following remarks on the caliber question:

"It is useless to try to perforate the belt armor, for, in any case, it is only a lucky accident that it is struck. Aim should be taken at the lighter armored parts of the ship above the belt line. It is a well-known fact that the Russian ships turned turtle when hit above this point, for in rough weather such a shot is quite as effective as a shot under water.

"As an example, we can refer to the English battleship *King Edward VII,* which, above the water-line plate proper (299

millimeters thick), has armor 5 meters high and from 203 to 178 millimeters thick. In battle the whole fire will be turned on this surface, and this armor must be penetrated at a distance of from 4,000 to 6,000 meters. The medium calibers of 16.5 and 19.4 centimeters cannot serve this purpose. On the other hand, the 24-centimeter model 1902, is the most suitable gun for this end. A heavier equipment, with 30.5-centimeter guns, is not necessary, as the 24-centimeter can accomplish this task as well, and at the same time it has the advantage of lighter weight and more rapid fire. A double turret for a 24-centimeter gun weighs 400 tons, while that of a 30.5-centimeter weighs 800 tons, so that it is possible to install a double number of 24-centimeter guns in place of the 30.5-centimeter.

Lockroy proposes, therefore, to replace the four 30.5-centimeter guns given in the minister's report by eight 24-centimeter, thus giving the ship twenty 24-centimeter guns. Each gun should be provided with 200 shells. The firm of Schneider-Canet is working in the direction of a rapidity of fire of three shots per minute from its 24-centimeter guns. Thus the 24-centimeter gun possesses all the advantages of the medium artillery and the power of the heavier weapon. Such a ship (as proposed by Lockroy) would combine the qualities of those provided with heavier artillery exclusively, such as the *Dreadnought* and of those that are equipped partly with heavy and partly with medium calibers.

"The advantage to be gained from the uniformity of caliber alone would justify this equipment. War is so complex a matter that its instruments must be simplified as much as possible. The varying types of ships, of guns and of projectiles, are liable to bring disaster. The ideal is one type of ships, one type of guns, one type of projectiles."

The Italian Engineer Lorenzo d'Adda has published in "Moniteur la Flotte" a sketch showing an arrangement of the twenty guns suggested by Lockroy so as to provide each turret with the greatest possible arc of fire.

It is well to compare the weight of the projectiles of the following ships: *Dreadnought*—representing a type of exclu-

sively heavy artillery; *Danton*—mixed artillery; and that of the type proposed by Lockroy—a type of lighter guns.

The following are the weights of the different armor-piercing shells and the expected rapidity of fire:

Country.	Caliber.	Weight of shot.	Shots per minute.
	cm.	kg.	
England,	30.5	385	2
France,	30.5	440	2
France,	24	220	3

Table showing the total weight of shots of a salvo:

Ship.	Broadside.	Stern.	Bow.
Dreadnought,	3,080	2,310	2,310
Danton,	3,080	1,760	1,760
Type *Lockroy,*	3,080	2,640	2,640

The total weight of projectiles for one minute of rapid fire:

Ship.	Broadside.	Stern.	Bow.
Dreadnought,	6,160	4,620	4,620
Danton,	7,480	4,400	4,400
Type *Lockroy,*	9,240	7,920	7,920

Thus the Lockroy-type ship is superior, if the total weight of the projectiles is to be regarded as a basis of comparison.

D. Propositions of Deputies Bienaime and Leygue.

1. Caliber.

Admiral Bienaime recommends that the equipment in armament of the *Dreadnought* be followed. He does not consider the more rapid firing of the lighter pieces as an important advantage, because undoubtedly there will be invented some means to give the heavier artillery equal rapidity. Further, an equal weight of projectiles divided among a fewer number of shots gives better results than if divided among many shots. That, he considers, is a maxim.

The proposition of Honore Leygue can be summed up as follows:

a. Even a relatively thin armor plate can stand a shower of rapid fire from lighter guns (although considerable in the

combined weight of the shots) without being seriously damaged. Therefore the caliber should be large.

b. The amount of explosive is greater in larger calibers, and as the penetrating force of a larger caliber is greater, the walls of such a shell can be correspondingly thinner. This is impossible with small calibers; consequently, a large-caliber shell can contain not only absolutely more explosive, but even relatively more than a smaller caliber.

Now the minister has himself declared that the results of the explosion of a projectile are more effective than those produced by perforation of the armor; and as the larger-caliber shell contains a relatively greater amount of explosive than that of the small-caliber gun, therefore the heavier piece is preferable even from this viewpoint. Thus the minister is beaten by his own arguments, and the armament equipment of the *Dreadnought* must be considered superior.

Besides, the question of the caliber cannot be discussed alone without reference to other points. The speed of the ship is also a very important factor; for that ship which has a greater speed can select the most suitable distance for the greatest fire effect with the least risk. From this standpoint the *Dreadnought,* with her 21 knots, is also superior to the proposed ship of 19 knots.

2. The Projectiles.

Admiral Bienaime said, in regard to the minister's view on the projectiles: "There was much discussion on the subject of the uniformity of projectiles. I am myself for uniformity. Still, there are cases where uniformity is impossible. We cannot use armor-piercing shells in operations against a seacoast battery, much as we would like to push the uniformity to the extreme. There is necessarily a limit in the demand for uniformity."

E. Laubeuf's Proposition.

Laubeuf, Chief Engineer of the French Navy, recommends in "Le Yacht" the following armament for the new battleships:

Eighteen 30.5-centimeter guns in double turrets.

Several 12 and 7.5-centimeter guns for fighting torpedo boats.

Speed 22 knots and displacement 26,000 tons.

He bases this data on the general development of the question of caliber, the results of which lead to his "Battleship of the Future."

F. Criticism of the 27.4-Centimeter Guns.

Ch. Larroze published in "Le Yacht" an exhaustive criticism of the type recommended by Bos, especially the 27.4-centimeter guns. He thinks it erroneous to suppose that the double turret of the 27.4-centimeter guns lighter than that of the 30.5-centimeter. As the old 30.5-centimeter gun is 40 calibers long, and the new 27.4-centimeter gun should have a length of 45 calibers, the weight of the guns will be approximately the same.

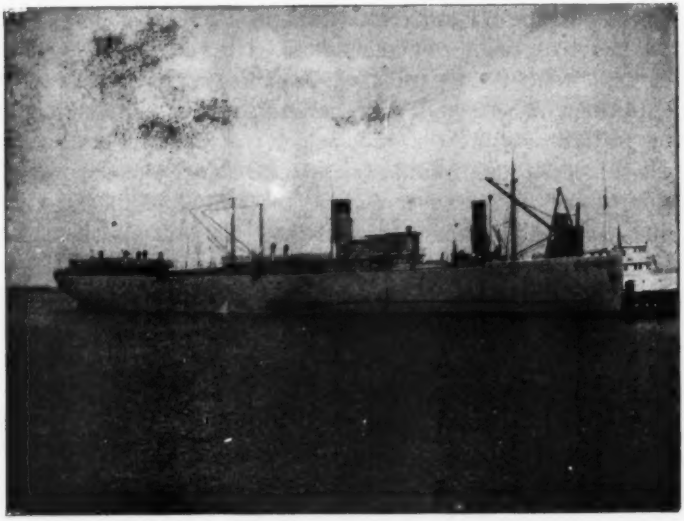
Further, on account of the considerable increase in the weight of projectiles and the muzzle velocity of the 27.4-centimeter guns, model 1902, it will have a muzzle energy almost equal to that of the 30.5-centimeter guns; the weight of the carriage and apparatus for the control of the recoil will also be equal in both guns, because the weight of these parts are proportional to the muzzle energy, and not to the caliber. The displacement of 18,000 tons recommended by Bos is also far insufficient for sixteen of the new 27.4-centimeter guns; 21,000 tons is the least displacement required for this purpose.

OIL *VS.* COAL AS A MARINE FUEL.

By G. P. Blackiston.

The use of oil as a fuel for ships is rapidly increasing in popularity.

This is due, to a great degree, to its noticeable economy, not only in the actual cost of the fuel itself, but in labor for handling and storage space.



U. S. Hydraulic Dredge "Galveston," which is Operated Entirely by Oil Fuel.

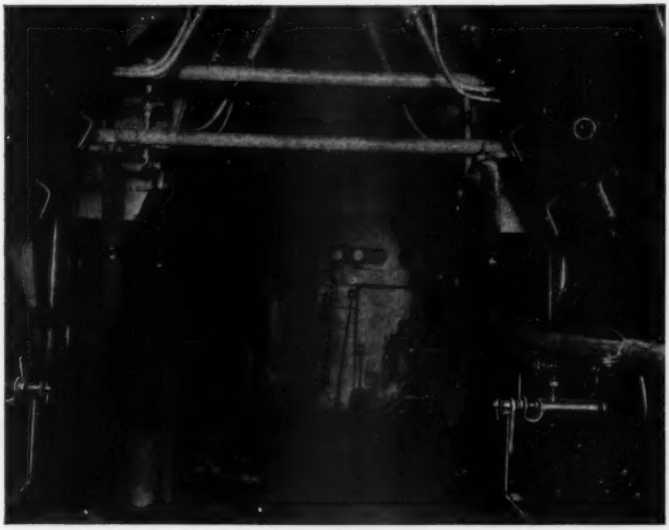
From three to three and one-half barrels of oil do the work of one ton of best quality coal, and from this can be quickly figured the saving in favor of oil.

As three and one-half barrels of oil weigh about 1,000 pounds, it can readily be seen that oil fuel for a trip weighs only half as much as would coal.

The water-ballast bottoms may be used for storing the oil (sea water being pumped into each compartment where the oil has been taken out), so that the space ordinarily required for coal may be used for cargo, increasing the carrying capacity of the ship.

As the oil is fed mechanically by pumps to the boiler, about one-third of the number of stokers are required, making a large saving in wages, board and accommodations.

Due to the fact that the oil can be loaded in about one-third the time required for the coal, more trips can be made. The speed is also increased about 20 per cent. by oil fuel.



INTERIOR OF THE BOILER ROOM OF THE U. S. HYDRAULIC DREDGE "GALVESTON," SHOWING THE FUEL OIL EQUIPMENT AS SHOWN BY THE TATE JONES.

Combined with these pronounced advantages, a perfect control of the fire is had at all times. Accordingly, the fire can be changed almost instantly from a low to a most intense heat.

The fire is steady and regular, the steam pressure, therefore, being always constant; while the temperature of the stoke hole

is perceptibly lower, owing to the fact that the furnace doors are never opened and hot cinders and ashes are entirely absent.

A very interesting comparison of the advantages between oil and coal can readily be seen by the following data taken from the log of S. S. *Venus,* plying between New Orleans and Simon, Costa Rica, C. A.:

Coal used, 24 hours, tons	30
Oil used, 24 hours, barrels	96
Distance traveled in round trip, miles	2,600
Knots per hour with coal	9
oil	11¾
Oil pressure at burners, pounds	33
Total oil used on trip, barrels	1,000
Indicated horsepower	950

Looking closer into the subject, we find that crude petroleum or fuel oil is a mixture of a number of hydro-carbons, all having the same component parts, and their differences being entirely due to the varying proportions of these constituents. Each of them makes a very good fuel under certain conditions, but to a misunderstanding of these conditions is due much of the adverse criticism of the use of oil as a fuel that has happened of recent years, and to an appreciation of these conditions and the use of proper heating and burning appliances will be due the success that this class of fuel will achieve.

1. The oil used must be of sufficiently high fire test. If this condition is observed it will dispose entirely of the objection on the score of safety frequently urged against this fuel. In fact, oil with a fire test of, say, 180 degrees to 200 degrees Fahrenheit is as safe as coal, which has been known to ignite from spontaneous combustion. Oil with a fire test of 250 degrees or 300 degrees Fahrenheit may be stirred with a red-hot poker without being ignited, or a shovelful of hot coals thrown into it will sink and be extinguished.

2. The oil must be supplied to the burners under a sufficient and uniform pressure; this is best accomplished by means of small pumps and pressure chambers.

3. The oil should be pre-heated to facilitate atomization.

4. The burner should feed the oil in a finely atomized condition; a properly constructed burner will show no dark stream of oil entering the furnace from its tip; instead the oil will emerge from it in an almost imperceptible spray or vapor.

5. The steam should be superheated before going to the burner.

6. Just the right proportion of air should be admitted to the fire box or combustion chamber to completely burn the fuel. Both experience and scientific experiment have laid it down as a general rule that an excess over the proper amount of air is not only useless, but actually exercises a cooling effect in the combustion chamber. In the practicability of admitting just the right amount lies one of the advantages of liquid over solid fuel.

7. The combination heater and pressure chamber should be fitted with a proper arrangement of relief valves to permit an excess of oil to return to the tanks.

The United States Government several years ago became very much interested in this fuel, and after making a thorough study of the subject decided to install an oil-fuel system in the gigantic hydraulic dredge *General C. B. Comstock,* built for Gulf of Mexico service.

The Tate, Jones Co., of Pittsburg, were awarded the contract, due to their peculiar burner, which assured maximum results. So successful was this that the same style equipment was specified and installed in the new United States Army hydraulic dredge *Galveston.* This monster, with her two thousand indicated H.P. engines, was built by the Maryland Steel Co., and is to be placed on duty in the Galveston harbor.

With the increase of production in crude oil this method of heating will rapidly advance, due to the manifold advantages over coal or other fuels.

THE RECIPROCATING ENGINE IN MARINE PRACTICE AND ITS PROBABLE FUTURE.

By D. Gibson.

Paper read before the Manchester Association of Engineers.

The following paper is intended to review the types of marine reciprocating engines now prevailing, and to indicate the most modern features in each; also to note the considerations that usually determine the adoption of each type. A few tentative remarks as to the probable future of reciprocating engines are appended.

Modern competition, modern requirements and the spirit of strict utility have set their mark on marine engines more drastically perhaps than on any other machine.

The beautiful finish, the variety of fancy in minor detail, the vagaries in design of the various gears and general outlines that characterize the engines built a generation ago are gone, but in their place we have a marvel of efficiency, cheapness, accurate construction and reliability. General practice and details have been stereotyped and simplified until marine engines today are as uniform as possible short of actual standardization.

TRIPLE-EXPANSION THREE-CRANK ENGINES.

Two sets of this type are illustrated and considered, one for powers up to 2,500, and the other for higher powers up to, say, 4,000. Fig. 8 shows a typical set of up-to-date triple-expansion engines for horsepowers of 700 to 2,000. The general features to be noted as representing modern practice are simplicity and accessibility. The front columns or pillars are of turned wrought steel, giving a fine, open front. The bedplate is of a simple character, made in two or three pieces, and bolted together. The condenser, instead of forming part

of the entablature casting, as in older designs, is separate and made of steel plating. The cylinders are all bolted together to form one piece, instead of being braced together with ties. One valve chest and cover serves for the high and intermediate-pressure cylinders.

The boiler pressure is led to the inside of the H.P. valve, which exhausts at the top and bottom into the space common to the H.P. and I.P. piston valves. (See Fig. 1.) In this size

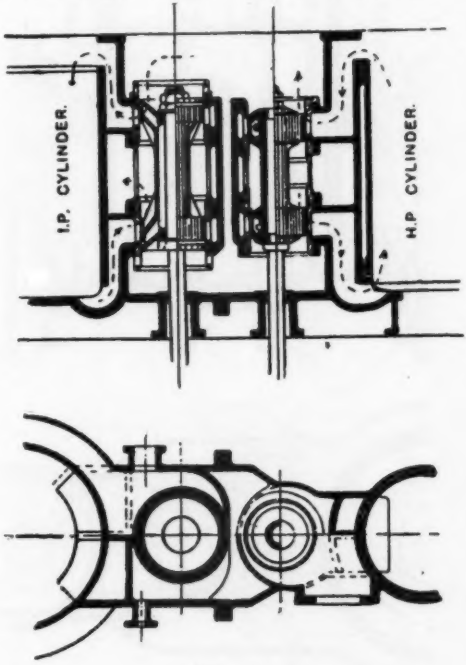


Fig. 1.

of engine the I.P. valve, although shown as a piston valve, is usually a slide valve of the simple "D," "Trick" or double-ported type, as shown in Fig. 2. The L.P. is *always* fitted with a double-ported slide valve. The connecting-rod top ends have gudgeon pins working in brasses set into the bottom end of the piston rods.

The guides or slide bars are of the slipper type, a detailed section being shown in Fig. 3. It will be noted that there is a space behind the slide bar to allow of cold sea-water circulation for cooling purposes, which is a common practice in marine work. The air, circulating and feed pumps are all worked by levers from the L.P. engine, and the whole set is self-contained.

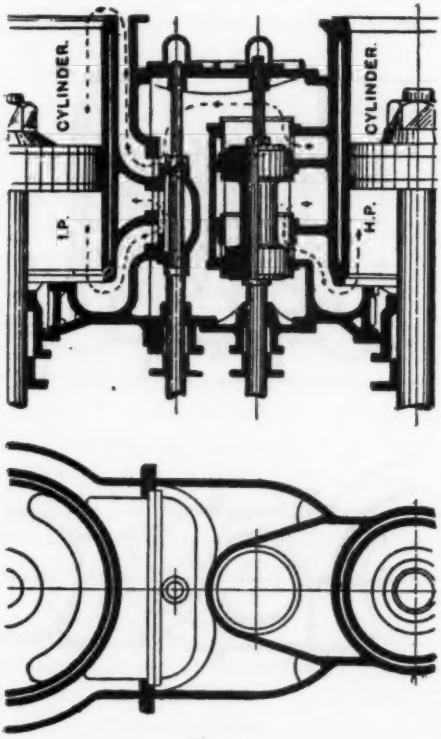


Fig. 2.

The design we are considering shows a set of engines for a single-screw vessel now being constructed for the Goole and Continental fast freight service of the Lancashire and Yorkshire Railway. The cylinder diameters are: H.P., 22 inches; I.P., 36 inches; L.P., 61 inches; with a stroke of 39 inches. The

I.H.P. is 1,800, with 90 revolutions per minute, which will give the vessel a sea speed of a little over 13 knots loaded. The weight of these engines, with their boilers, water and all accessories, is 325 tons, or 400 pounds per I.H.P. The boiler pressure is 180 pounds per square inch.

Fig. 8 shows a heavier type set of three-crank triple-expan-

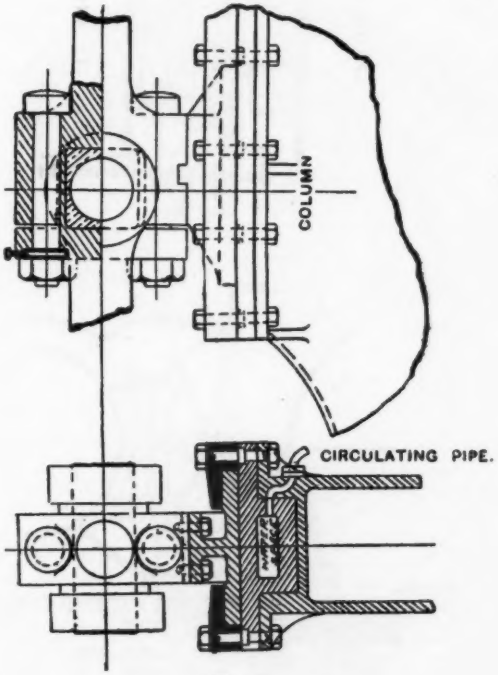


Fig. 3.

sion engines usually adopted for horsepowers of 2,500 to 4,000.

For additional stiffness the light columns in front may be replaced by massive cast-iron columns, the faces of which form the go-astern guides. The top ends of the connecting rods are of the double-bearing type, thereby gaining more service than can be obtained with the gudgeon class of bearing. The H.P. and I.P. valves, instead of being paired together, are usually

separate, the larger size and power of the engines necessitating a piston valve or valves on the I.P. cylinder.

Slide valves are troublesome appliances if fitted on the I.P.

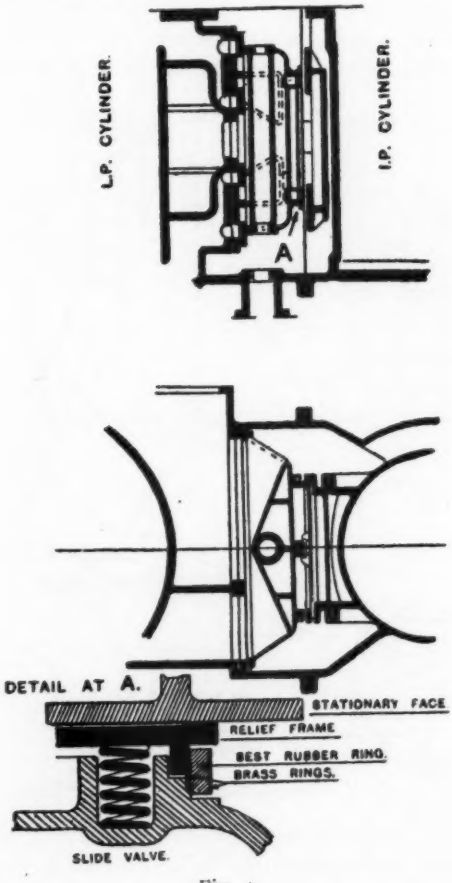


Fig. 4.

cylinder of large engines. In the largest sizes, whether triple or quadruple-expansion, the I.P. cylinder is fitted with two piston valves, side by side, worked from the valve gear by a connecting crosshead under the cylinders, and sometimes in

the steam space, as in this particular illustration. The L.P. slide valve is fitted with a relief frame to reduce the friction on the face, and also a small balance cylinder on top of the steam chest cover to ease the great weight on the valve gear.

A simple form of relief frame is shown in Fig. 4. The

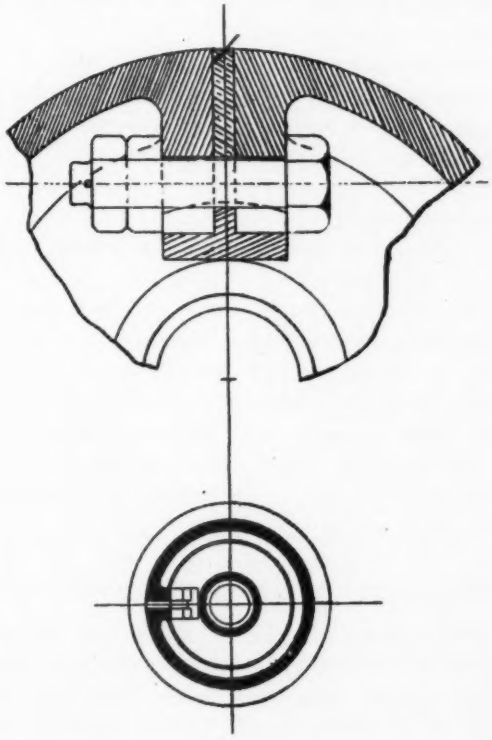


Fig. 5.

air pump is the only pump worked by the main engines. For powers above 2,500 I.H.P. it is found advantageous to have separate and independent steam-driven circulating and feed pumps, the former being a centrifugal pump and the latter a slow-working direct-acting pump of one of the many modern high-class designs.

In modern marine engines of whatever kind the "Stephenson" link motion is almost universal. No other type works in so well with the general arrangement of the engine, and the advantages to be gained by a more perfect steam distribution such as is obtained with the radial types of valve gear are exchanged for a cheaper, simpler, more easily arranged and more readily understood gear.

Where piston valves are not simply solid discs or plugs the packing rings are usually as shown in Fig. 5. With this ring wear is taken up by inserting a liner between the lugs and tightening up and locking the bolt. By carefully filing and adjusting the liner, the shape of the circumference of the ring can be made to coincide exactly with and to fit the valve chamber. The piston rods are almost invariably fitted with metallic packing of one of the spring floating class, having no textile material in its construction. These packings very soon pay for themselves. The particular engine shown in Fig. 9 has an I.H.P. of 3,000, with 70 revolutions per minute. The cylinder diameters are: H.P., 28 inches; I.P., 48 inches; L.P., 78 inches; with a stroke of 54 inches. The total steaming weight (boilers, water and propelling machinery) is 562 tons, or 420 pounds per I.H.P. The engine, as it stands, weighs 160 tons.

GENERAL REMARKS ON TRIPLE THREE-CRANK ENGINES.

The boiler pressure for triple-expansion engines has steadily risen from 150 to 180 pounds per square inch, which is the limit of economical high pressure for three-stage expansion. Such engines are seldom fitted with steam jackets, and superheating is the exception rather than the rule. Given sufficiently large boiler capacity to avoid undue forcing, with its evils of imperfect combustion and wet steam, such engines give a surprisingly high efficiency.

Three-crank triple engines are adopted for all powers up to about 4,000 I.H.P. per set. They are now not often adopted

for higher powers. The largest sets of this type now running are in the American liner *New York* and the White Star liners *Majestic* and *Teutonic,* the cylinder sizes and powers being:

	H.P.	I.P.	L.P.	Stroke.	I.H.P.	No. of sets.
	Ins.	*Ins.*	*Ins.*	*Ins.*		
New York.....	45	71	113	60	9,200	2
Teutonic and *Majestic*	43	68	110	60	8,500	2

About 70 per cent. of the world's commerce is carried on by ships fitted with three-crank triple engines and having single or twin screws, according to the power required. The speeds of these vessels vary from 8 to 14 knots per hour, but the most of them are below 12 knots. For a 12-knot speed the power required will seldom exceed 4,000, even for very large vessels, and for this power and upwards twin-screw engines are generally adopted. The greater number of three-crank triples in use do exceed 3,000 I.H.P. per set. By introducing twin screws two sets of engines of half the power can be fitted with a considerable saving in fore-and-aft space, with handier and more easily overhauled engines, and with the ability to bring the vessel home safely with one engine in the event of a broken shaft or total derangement of the other.

The ships we are considering are full bodied for large carrying capacity, and with their great depth of mid section, and therefore great structural stiffness, the comparatively low powers mentioned cause no appreciable vibration. It is in these vessels and with these powers that the three-crank triple practice is established.

The revolutions per minute vary from 60 to 80. This rate of rotation requires large propeller proportions, which are the most suitable for economical all-around work with slow bluff-lined vessels, particularly for driving into a head wind and sea.

Large diameter and surface give a propeller a greater ability to efficiently adjust itself to varying resistance, and thus minimize the loss due to excessive slip. This loss is at a maximum with propellers of small diameter and pitch and high rate of

rotation, if applied to the slow speed and varying conditions of loading and weather resistances of a steamer of the tramp type.

QUADRUPLE-EXPANSION FOUR-CRANK ENGINES.

Where the power required per propeller is 4,000 I.H.P. and upwards, particularly in vessels trading to long distances, modern marine practice is increasingly finding it expedient to adopt quadruple-expansion four-crank engines, with boiler pressures of 210 to 220 pounds per square inch. The extra weight of engines and boilers due to the higher pressure and ratio of expansion is to some extent compensated by the saving in fuel carried and consumed. The largest ocean liners, rivals of some of those fitted with turbines, notably the Cunard twin-screw steamship *Caronia* (sister to the turbine S. S. *Carmania* and the huge vessels of the White Star Line—the *Baltic, Cedric, Celtic* and the *Adriatic)* are equipped with twin-screw four-crank quadruple-expansion engines.

Not only at 4,000 I.H.P. and upwards, but for powers as low as 2,500 I.H.P., there are now many vessels giving entire satisfaction and showing greater economy with four-crank quadruple engines.

Compared with three-crank triple-expansion engines of 180 pounds working pressure, the weight of the four-crank quadruple engine per I.H.P., including boilers and their water, is 8 to 10 per cent. heavier with the same revolutions, although the boiler proportions may be 5 per cent. less. The saving in fuel averages from 6 to 7 per cent. in favor of quadruples.

Full figures as to net economy are not easily obtainable, but the addition of an extra engine with the extra cost of repairs and maintenance due to the higher pressure makes an inroad upon the saving in fuel, especially with low-powered ships of, say, 2,500 I.H.P. and thereabouts, where initial cost, number of crew and consumption of stores are cut down to the lowest point, and the addition of even one man in the engine-room crew makes an appreciable difference in the percentage of working cost. With large powers, however, the comparative

costs named above are not so great, whilst the 6 per cent. saving in fuel is an important figure.

Other compensating advantages also enter into consideration, the most important being the absence of vibration when quadruple-expansion four-crank engines are fitted. Vibration,

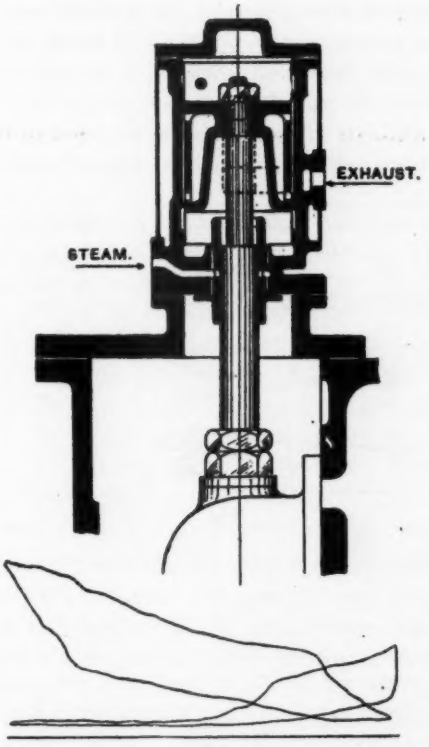


Fig. 6.

with its consequent heavy wear and tear on hull and machinery, on fast Transatlantic and other steamers equipped with the highest powered three-crank engines, not to speak of the discomfort to passengers, is a serious item, and immunity from panting and vibration alone is cheaply purchased by any in-

creased running cost that might be incurred with quadruple engines. Hence the now general practice of adopting them for high powers.

The subject of engine balancing is extensively dealt with in numerous text-books and papers, and does not lie within the scope of this paper; but it should be noted that the introduction of the four-crank principle, with the possibilities it opened up for what is known as the "collective" system of balancing, marks the most important advance in marine reciprocating engines during the past decade.

Various methods of arranging the sequence of the cylinders have been tried. Finality has been almost reached with the

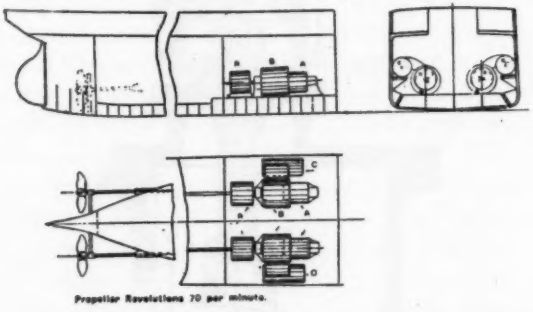


Fig. 7.

system known as the Yarrow, Schlick and Tweedy, whereby the spacing of the cylinders, the weights of the reciprocating parts and the crank angles are so arranged as to enable the unbalanced or disturbing forces to neutralize each other or to "cancel out."

With a less number of cranks than four this "collective" system cannot be adopted; and a balance approximately as good as the "collective" system can only be arrived at by a combination of rotating balance weights on the crank, and reciprocating bob weights worked by cams on the shaft, an arrangement that does not lend itself to good practical management.

Fig. 9 shows a set of quadruple four-crank engines balanced

on the Yarrow, Schlick and Tweedy system. The cylinder diameters are: H.P., 23 inches; first I.P., 31 inches; second I.P., 48 inches; L.P., 71 inches; with a stroke of 48 inches. The boiler pressure is 215 pounds per square inch. The I.H.P. is 2,500 at 72 revolutions per minute. The drawing is typical, and although the particular set is of low power, the general features are the same for the highest powers, the only details that alter in the latter case are the adoption of double-bearing connecting-rod top ends, and the substitution of piston valves for slide valves in the intermediate cylinders.

TRIPLE-EXPANSION FOUR-CRANK ENGINES.

This type came into being by reason of the adaptability of the four cranks to proper balancing. As has been stated, for ordinary cargo and other steamers of moderate speed the three-crank triple engine is for all practical purposes sufficiently balanced. With express Channel steamers, cruisers and warships generally, the high power required and the low machinery weights allowable—for naval architects' reasons—necessitate a high rate of revolution varying from 140 to 250 per minute to get the power. At such rates of speed the vibration set up by three-crank engines is very objectionable and sometimes destructive, and is the more pronounced in that such ships are of very light construction and often of extremely shallow draught and midsection.

The four-crank triple, with the H.P. and I.P. cylinders in the middle and the L.P. cylinder at each end, balanced on the Yarrow, Schlick and Tweedy system—in the same manner as a quadruple—has been introduced with marked success in lieu of the three-crank engine. Most of our cross-Channel steamers and warships are now fitted with this type. It is the chief competitor of the steam turbine, and it is this engine, notwithstanding its high standard of development, that the turbine is now extensively displacing.

Quadruple-expansion engines are sometimes fitted instead of triples, but where the conditions of speed and weight allowed

are severe—as in this type of vessel—the extra 8 to 10 per cent. of weight of boilers and machinery over triple expansion is inadmissible, notwithstanding the superiority of the quad-

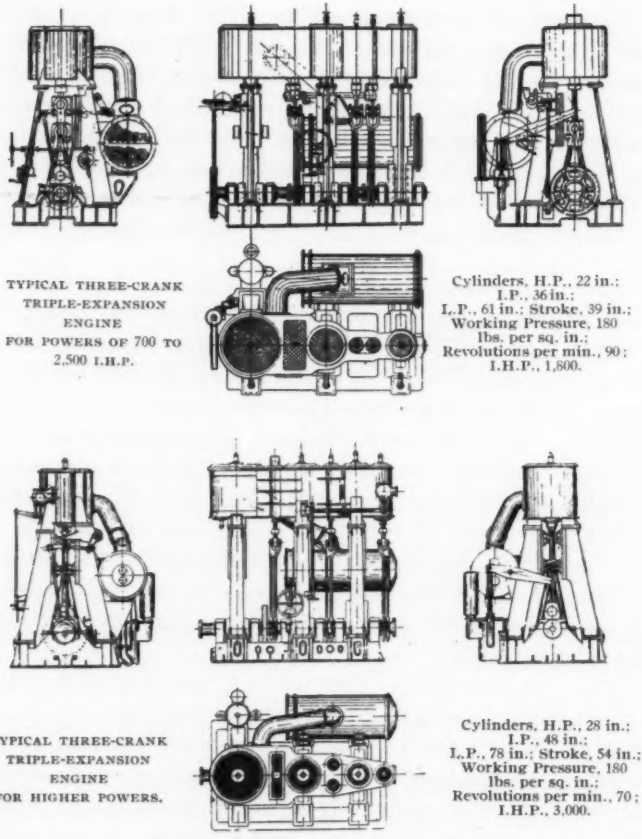
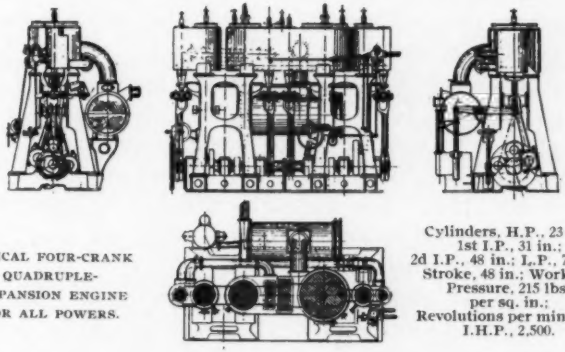

TYPICAL THREE-CRANK TRIPLE-EXPANSION ENGINE FOR POWERS OF 700 TO 2,500 I.H.P.
Cylinders, H.P., 22 in.; I.P., 36 in.; L.P., 61 in.; Stroke, 39 in.; Working Pressure, 180 lbs. per sq. in.; Revolutions per min., 90; I.H.P., 1,800.
TYPICAL THREE-CRANK TRIPLE-EXPANSION ENGINE FOR HIGHER POWERS.
Cylinders, H.P., 28 in.; I.P., 48 in.; L.P., 78 in.; Stroke, 54 in.; Working Pressure, 180 lbs. per sq. in.; Revolutions per min., 70; I.H.P., 3,000.

Fig. 8.

TYPICAL THREE-CRANK TRIPLE-EXPANSION ENGINES.

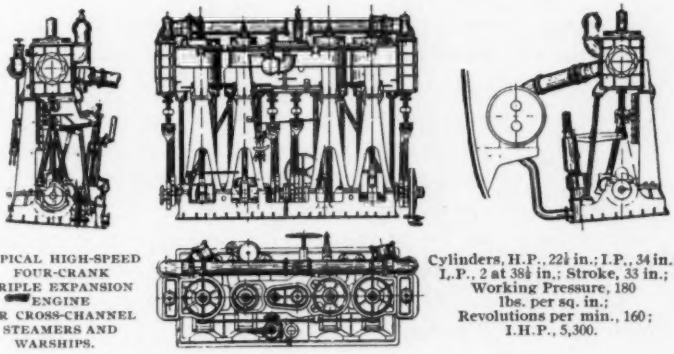
ruple in fuel economy. Another objection to the quadruple engine in the fast Channel steamers is the falling off in economy that takes place when the steam pressure is not rigorously

maintained at the designed figure. Boiler power for weight reasons is cut down as low as possible, and if the quality of the fuel is a little below par the pressure falls, with the result that a ratio of expansion no greater than that of triple-expan-



TYPICAL FOUR-CRANK QUADRUPLE-EXPANSION ENGINE FOR ALL POWERS.

Cylinders, H.P., 23 in.; 1st I.P., 31 in.; 2d I.P., 48 in.; L.P., 71 in.; Stroke, 48 in.; Working Pressure, 215 lbs. per sq. in.; Revolutions per min., 72; I.H.P., 2,500.



TYPICAL HIGH-SPEED FOUR-CRANK TRIPLE EXPANSION ENGINE FOR CROSS-CHANNEL STEAMERS AND WARSHIPS.

Cylinders, H.P., 22½ in.; I.P., 34 in.; L.P., 2 at 38½ in.; Stroke, 33 in.; Working Pressure, 180 lbs. per sq. in.; Revolutions per min., 160; I.H.P., 5,300.

Fig. 9.

TYPICAL FOUR-CRANK ENGINES.

sion engines is obtained, with heavier weight and greater initial cost of machinery and boilers.

Fig. 9 shows an up-to-date set of four-crank triple engines fitted in express Channel steamers. The type varies but

slightly in details for warships. This set is one of the twin-screw pair fitted in one of L. and Y. and L. and N. W. Joint Railway Companies' steamers for the Fleetwood and Belfast service. The cylinder diameters are: H.P., 22½ inches; I.P., 34 inches; L.P., two at 38½ inches; length of stroke, 33 inches; and the combined I.H.P. for the two sets is 5,300 with 160 revolutions per minute. The working pressure is 180 pounds per square inch. The speed of vessel with this power is 19.5 knots per hour. The weight of the engines alone as they stand is 73 tons per set, including its condenser; and the weight per I.H.P. of boilers, water and all machinery is 254 pounds per I.H.P. The diagonal bracings on the front turned-steel columns will be noted. Piston valves are fitted on the H.P. and I.P. cylinders.

The two L.P. slide valves and the heavy intermediate piston valves are fitted with assistant cylinders to take up the momenta and also to assist the working of the quickly moving heavy valves, thus easing the stress and shock on the valve gear. With these assistant cylinders the steam is admitted to the top and bottom of the small piston by an ingenious arrangement of ports in the cylinder barrel.

This is an improvement on the type shown on the L.P. valve gear in Fig. 8, where the bottom of the small piston is always open to the steam space and the top to the condenser, and the appliance serves simply as a support to the heavy valve. The momentum at the top of the travel is negligible as compared with that in the higher speeded engine under notice.

The vibration with the four-crank triple engine is not much more than with turbines, although the sense of vibration is increased by the noise of the engines unless the bearings—particularly those of the connecting rods—are kept in very good adjustment. Then, again, the larger propeller tips, breaking the surface of the water with greater force per tip, give a more distinct and heavier throb than those of turbines, which lie deeper, and in more solid water, and are of a less diameter, with a much higher rate of rotation.

STEAM JACKETING.

In reviewing modern reciprocating engines a note on steam jacketing may not be out of place. Steam jacketing has no recognized part or advantage in current marine practice. The general opinion of engine builders—in view of the conflicting nature of the results reported—seems to be that for triple-expansion engines the range of temperature in each cylinder is so small as to eliminate it from commercial consideration. A practical objection often urged against it is the possibility of allowing the jackets to fill with water through neglect, whilst, on the other hand, it is often held that many jackets overheat their cylinders.

The first objection can be got over by fitting efficient steam traps, and the second by the introduction of reducing valves capable of easy adjustment, the latter facilitated by the provision of a pressure gauge (kept carefully calibrated) on each jacket. These are all refinements which involve expense and require careful attention. It is not easy to ensure strict watchfulness at sea on the latter point, owing to the multifarious duties required of the engineer on watch.

Whether it is possible for the jackets to overheat the cylinders with saturated steam at boiler pressure is open to discussion. In some trials made with fully jacketed triple-expansion engines at Owens College, it was found that when all the jackets were filled throughout with steam at full boiler pressure, 19.4 per cent. of the total heat supplied was converted into work. Without steam in any of the jackets this percentage fell to 15, showing a gain of over 25 per cent. in favor of steam jacketing.

The author has not been able to find any authentic records of similar figures in marine practice, nor anything approaching it.

The four-crank triple-expansion engines of H.M.S. *Powerful* have steam jackets on all the cylinders. Steam is supplied at 210 pounds pressure at the stop valve. The pressure in H.P. jackets is 210 pounds, on the I.P. jackets 100 pounds, and on the L.P. 25 pounds. The writer has not seen any

records of results with and without jackets in the case of this or similar warships. The provision of steam jackets, however, has a peculiar value in warships, where the full power is seldom required, and where the vessel has to make long voyages at very low powers, perhaps one-sixth of the total power, in which case the L.P. cylinders are doing little or no work, and are virtually condensers. In this case the steam jackets can be regulated to give the best temperatures to the I.P. and L.P. cylinders for most powers.

Those who have had charge of triple-expansion engines at sea will have noticed the great amount of condensation that takes place in the intermediate cylinder. Some engines are much worse than others, due, no doubt, to the cylinder ratios and cut-offs not being of the best proportions to suit the particular power at which the engines usually run, or to the wet quality of the steam supplied from the boilers. Even with the best packing the amount of water lost from the I.P. piston-rod glands is very considerable, and is a serious item in a deep-sea steamship where all *make-up* boiler-feed water has to be evaporated from sea water by means of a special evaporator.

To minimize this loss the I.P. cylinder drain is continuously kept open a little. A better plan is to fit a smaller drain at the root of the stuffing box and to lead it into the hotwell. This, however, does not minimize the heat losses to the fullest extent. The writer, in company with many others, believes that it pays to fit a steam jacket to the I.P. cylinder—the best pressure being determined by experiment.

No trouble is experienced with condensation in the L.P. cylinder.

Seaton, in his "Manual of Marine Engineering," recommends steam jacketing in the I.P. cylinder in long-stroke slow-running engines; but fast-running engines, he thinks, can do very well without it.

SUPERHEATING.

Superheating has fallen into abeyance in marine practice since the early days when single-expansion engines were in vogue. At that time economies in fuel of 20 per cent. and

upwards were obtained by its introduction. Working pressures of 25 pounds to 35 pounds per square inch were the rule, with a superheat of 100 degrees Fahrenheit (corresponding to the temperature of saturated steam at 160 pounds gauge pressure). As pressures rose, and compounding was introduced, abrasion of valve and cylinder surfaces, and burning of the rod packings led to its abandonment. At the same time the gain due to higher pressures, with the consequent drier stream, and the use of compounding, obviated its necessity. However, thirty years after its disuse, superheating is again engaging attention in marine practice.

The current view of the practical engineer is that with boilers of ample capacity for their work, the quality of the steam is sufficiently dry to give a net economic result that can seldom be surpassed by superheating. This view may be commercially sound, for it is easy to lose what has been gained in fuel by cost of upkeep and by careless or incompetent management.

The great weight of superheaters is perhaps the chief objection. There remains a great deal to be done in design, and by the introduction of superior metals, before superheating can become a general practice for marine work. The marine engineer does not strain after a high degree of superheat. If he can get reasonably dry steam he is satisfied. It is often stated that any superheat less than 100 degrees Fahrenheit does not pay; but the probability is that if the weight of superheaters could be afforded, a superheat of 100 degrees Fahrenheit, or even less, if the plant were installed in a large fleet of steamers, would in the aggregate show a reasonable saving on the outlay, with ordinary intelligent management.

There are several steamship owners now adopting superheating extensively. Net results are carefully guarded; but the continuance of the practice where tried indicates that it is satisfactory. The amount of superheat is about 150 degrees Fahrenheit, and the saving in fuel varies from 12 to 15 per cent. In some steamers where there is a good deal of priming the saving runs up very considerably, sometimes as high as 25

to 30 per cent. In many cases the coal per I.H.P. is as low as 1.2 pounds.

Internal lubrication, in the form of the very finest high flash-point pure mineral oil, is necessary, and this must be used as sparingly as possible, the usual quantity being about one gallon per 24 hours for each 1,700 I.H.P. The oil is introduced into the steam pipe by a positive mechanical appliance worked by the main engines themselves.

It may be mentioned for the benefit of those who may not know it that internal lubrication is almost entirely dispensed with in marine engines. The cylinder condensation gives, with saturated steam, sufficient lubrication of the valve and cylinder surfaces. A certain amount of oil gets into the cylinders from the lubrication on the piston rods. The greater part of this is caught by the feed-water filter, which is fitted in all modern steamers, and the remainder is corrected in the boiler by the injection of a limited amount of soda.

The necessity for internal lubrication with superheated steam is therefore a serious objection in the opinion of the average marine engineer, who is taught to regard the introduction of oil into his boilers as perhaps his greatest evil. In practice, however, it is found that if the very best oil be used, with proper regulation, and with sufficiently large filters, there is no noticeable deposit of oil or its compounds in the boilers.

The writer has heard of power-house reciprocating engines running with a superheat of 120 to 150 degrees without internal lubrication, but he has no authentic information as to this. Perhaps some reader of this paper may be able to corroborate it. It would be interesting to know something of the circumstances under which such an exceptional performance can be attained.*

*Experience with superheating in engines of the U. S. Navy has shown that it is easily possible to use superheated steam in vertical marine engines, without the use of any other internal lubricant except the introduction of a small amount of graphite, and the periodically wiped out and oiling or vaselining cylinders when they are examined. This superheat used in this case was, however, only about 50 degrees Fahrenheit. High superheat, however, requires the use of steel piping, valves and fittings, and the elimination of composition valves, castings, etc., wherever subject to the action of the superheated steam.

PROBABLE FUTURE OF THE RECIPROCATING ENGINE.

In venturing upon a forecast, the size and speed of vessels enter into the matter, and for our purpose we must divide them into four classes, on similar lines to the divisions in the foregoing part of this paper:

1. *Fast cross-Channel steamers.*

2. *Fast Atlantic liners from 18 knots up to the highest speed.*

3. *Very large freight carriers of the intermediate type of liners with speeds of 12 to 18 knots, and power varying from 4,000 to 10,000 I.H.P. and upwards.*

4. *Tramps and moderate-sized freight ships of 8 to 12-knot speeds where the power will not exceed, say, 3,000 I.H.P.*

As regards classes 1 and 2, everything at the present time points to the conclusion that for these classes the steam turbine has come to stay, especially for the highest speeds. As the designed speed for such vessels is reduced there is a limit below which it is not considered advisable to fit turbines. For large vessels this limit is 15 to 16 knots. For smaller vessels, such as cross-Channel steamers, the limit is a little higher, and is about 17 to 18 knots. Up to these limits twin-screw quadruple engines for large ships, and twin-screw four-crank triple for cross-Channel steamers, give the greatest satisfaction as to weight of machinery, non-vibration, neatness of general arrangement, reasonable cost and general efficiency.

The principal factors which determine the above-named limits are propeller diameters and revolutions. As the designed speeds fall below these limits displacement increases, and the lines of the ship become fuller, necessitating larger diameter of propellers with a consequent lower rate of rotation. This means greater weight and cost of turbines (if turbines are fitted), and the lower rate of revolutions is in the direction of least efficiency for turbines. Whenever turbines have been tried below the limits mentioned they have not been a success, and will not bear comparison with reciprocating engines.

On the other hand, for speeds above the limits mentioned, the turbine is the superior machine, especially for the highest speeds.

The enormous increase in H.P. required for a small increment of speed (which exceeds the cube and sometimes the fourth power of the speed) alters all factors greatly. The lines of the ship become extravagantly fine, necessitating the smallest possible displacement for the length of the vessel. These factors, together with speed, permit of the economical adoption of smaller-diameter propellers and high rates of rotation suitable for turbines. The size and form of turbines give scope for the distribution of power into three or four propeller shafts, thus allowing a wider choice in the size of propeller and turbine unit to give the best results.

The saving in machinery weights is about 20 per cent. in favor of the turbine, and the fuel consumption is about the same as the triple-expansion four-crank engine in cross-Channel steamers.

It must be borne in mind that, at the highest possible limit of speed there can be no adequate comparison between the two machines, because reciprocating engines cannot be fitted to give the same limiting speed as turbines on account of their extra weight. If reciprocating engines of equal power to turbines were fitted their extra weight would necessitate greater displacement and fuller lines of vessel to carry that weight, with the result that another and lower limit than the first is introduced.

For class 3 the combination of reciprocating engines with turbines—which is now receiving the closest attention in marine engineering—holds promise of coming into general use. The arrangement has not yet had sufficient practical trial to establish anticipated results, but it is now being tried in several large steamers, notably the new White Star liner *Laurentic* and the New Zealand Shipping Company's steamer *Otaki** (which the writer has had an opportunity of inspecting), and there is every reason to believe that there is a future for the combination system.

Those interested in turbo-reciprocating combinations will

*On trial this vessel showed a water consumption of 12.3 pounds per I.H.P. for all purposes, a result hitherto unparalleled in marine practice.

find the latest information upon it in the paper read by the Hon. C. A. Parsons before the Institution of Naval Architects in April of this year.

The combination system lends itself to a very good general arrangement, particularly for powers 6,000 I.H.P. and upwards, such as are used in the largest freight steamers and intermediate liners.

If the combination system should not prove to be a success the existing practice of quadruple-expansion four-crank engines—with twin or single screws, according to power required—will probably continue, and, in any case, it will certainly have its advocates and users.

For class 4, which is the largest class afloat, the writer believes that the greater proportion will continue to be fitted with the three-crank triple-expansion engine, and the remainder with the quadruple-expansion engine.

Some very good designs of the turbo-reciprocating combination have been drawn up for the comparatively low powers used in this class of steamer, such as 2,000 I.H.P., but the extreme simplicity, cheapness and economy of the three-crank triple for these powers, together with its large, single and reasonably efficient propeller, may be trusted to keep the field against any other system.

No doubt competition and the spirit of progress will stimulate the development of superheating for general use in marine practice, and when this has materialized a degree of net economy with triple-expansion engines will have been reached, which will be on the limit of steam engineering possibilities.

FORCED LUBRICATION.

A GENERAL DESCRIPTION OF THE INSTALLATION AND ITS OPERATION AS APPLIED TO LARGE MARINE RECIPROCATING ENGINES.

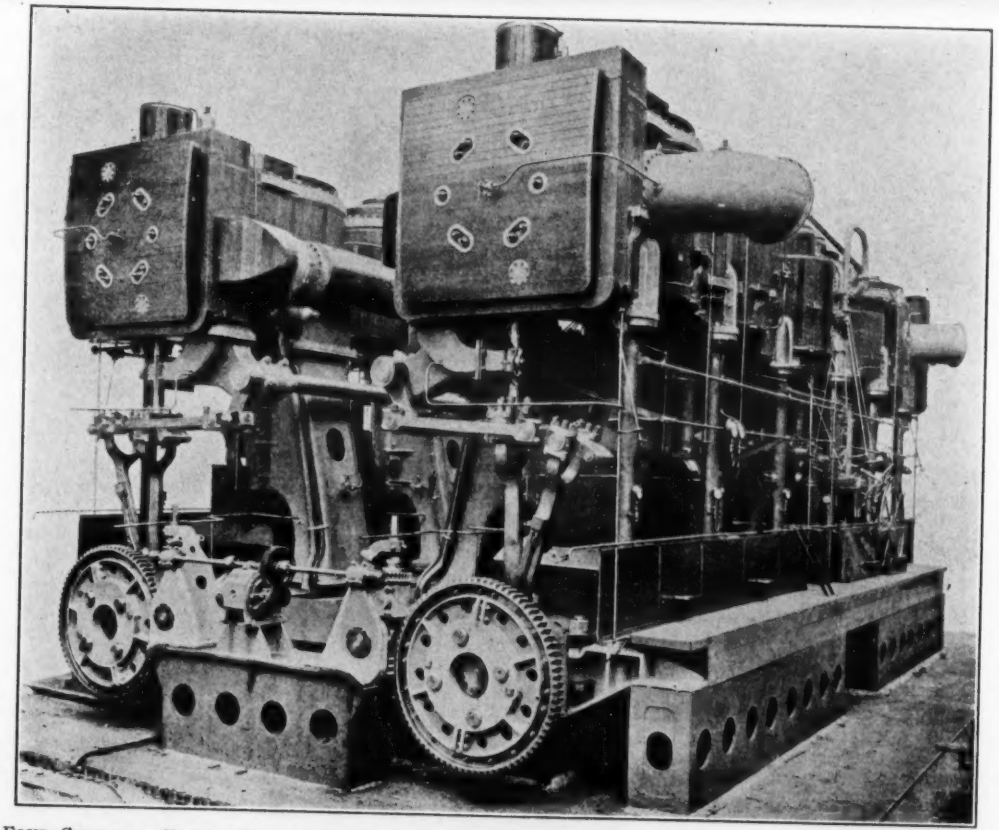
By Henderson B. Gregory, Associate.

Forced lubrication of engines is not a new idea. It has been successfully used for years in dynamo and blower engines of high rotary speeds, and is today the general practice for turbine and internal-combustion engines.

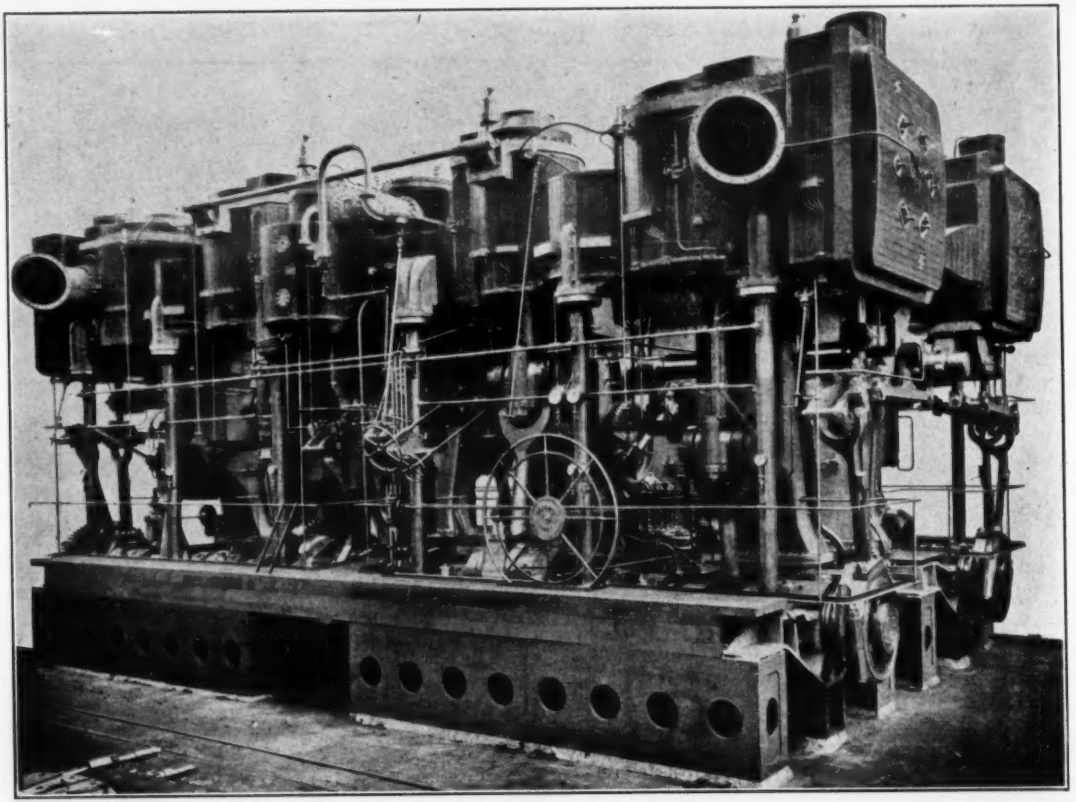
The application of a forced lubrication system as used on dynamo engines is illustrated by the cut showing the section of a dynamo engine and generator. A small plunger pump, operated by an eccentric on the engine crank shaft, takes the oil through a strainer in bottom of crank pit and forces it through a system of pipes to each main bearing. From the main bearings the oil goes to the crank pins through a diagonal channelway drilled through crank web. From the crank pin the oil goes through a pipe alongside connecting rod to the inside of crosshead pin, and from the crosshead bearing the oil is directed to the slide and drops down to the crank pin. The leakage at the various bearings also finds its way to the reservoir at bottom of crank pit and is used over again. New oil is supplied to make up any leakage through oil-tight casing.

Though old in principle, the application of forced lubrication to large marine reciprocating engines is of recent development, appearing first in the British Navy about three years ago.

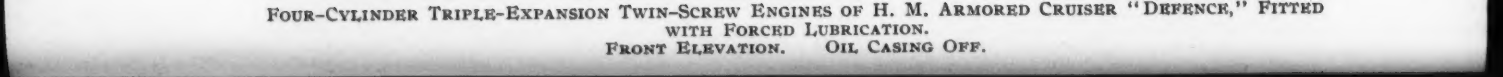
Superior efficiency and economy of oil are the principal claims for the forced system of lubrication over other oiling arrangements. As a matter of fact, both claims have been established beyond question by installations now in operation.



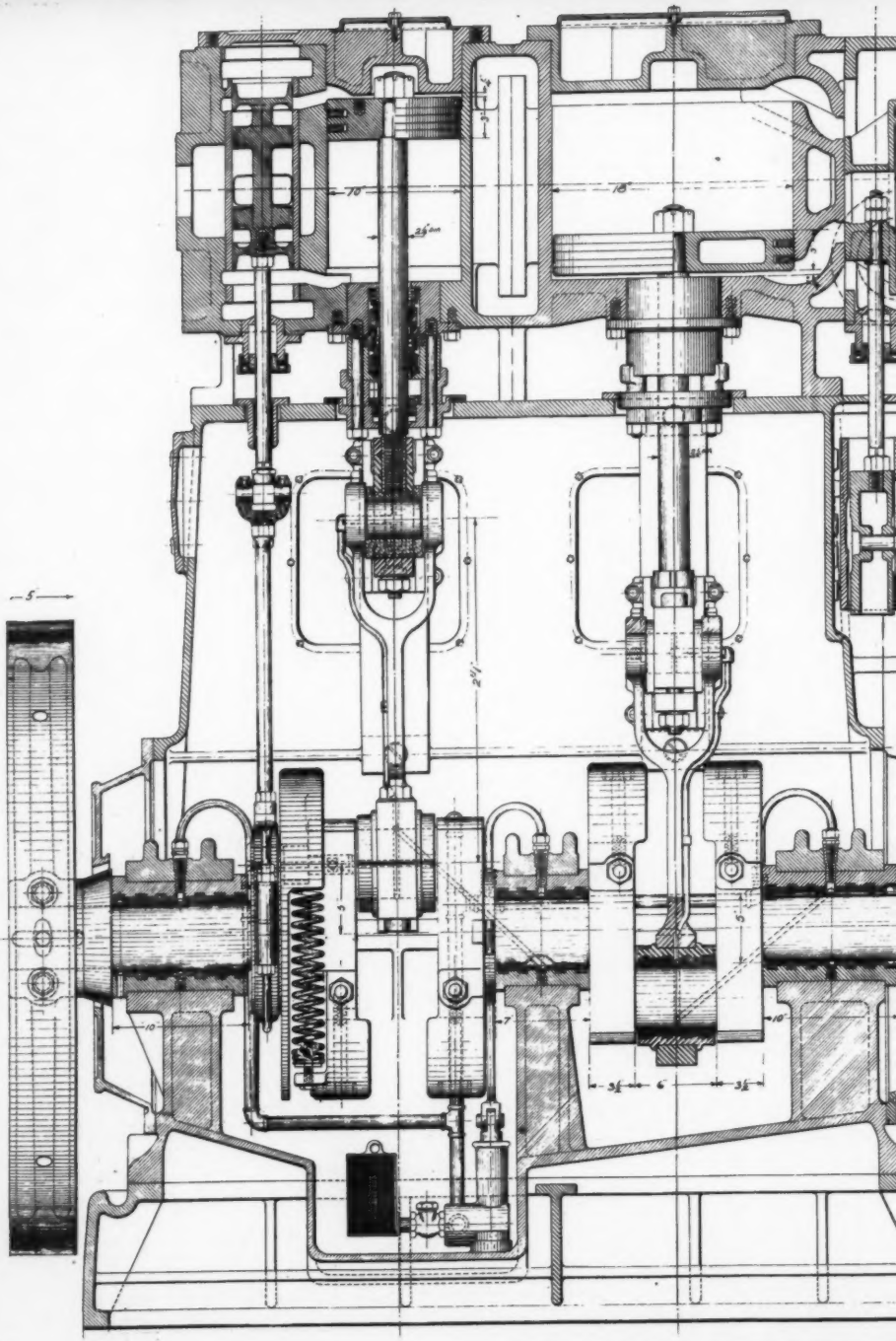
FOUR-CYLINDER TRIPLE-EXPANSION TWIN-SCREW ENGINES OF H. M. ARMORED CRUISER "DEFENCE,"
FITTED WITH FORCED LUBRICATION.
VIEW AT FORWARD END, SHOWING OIL CASING IN PLACE.



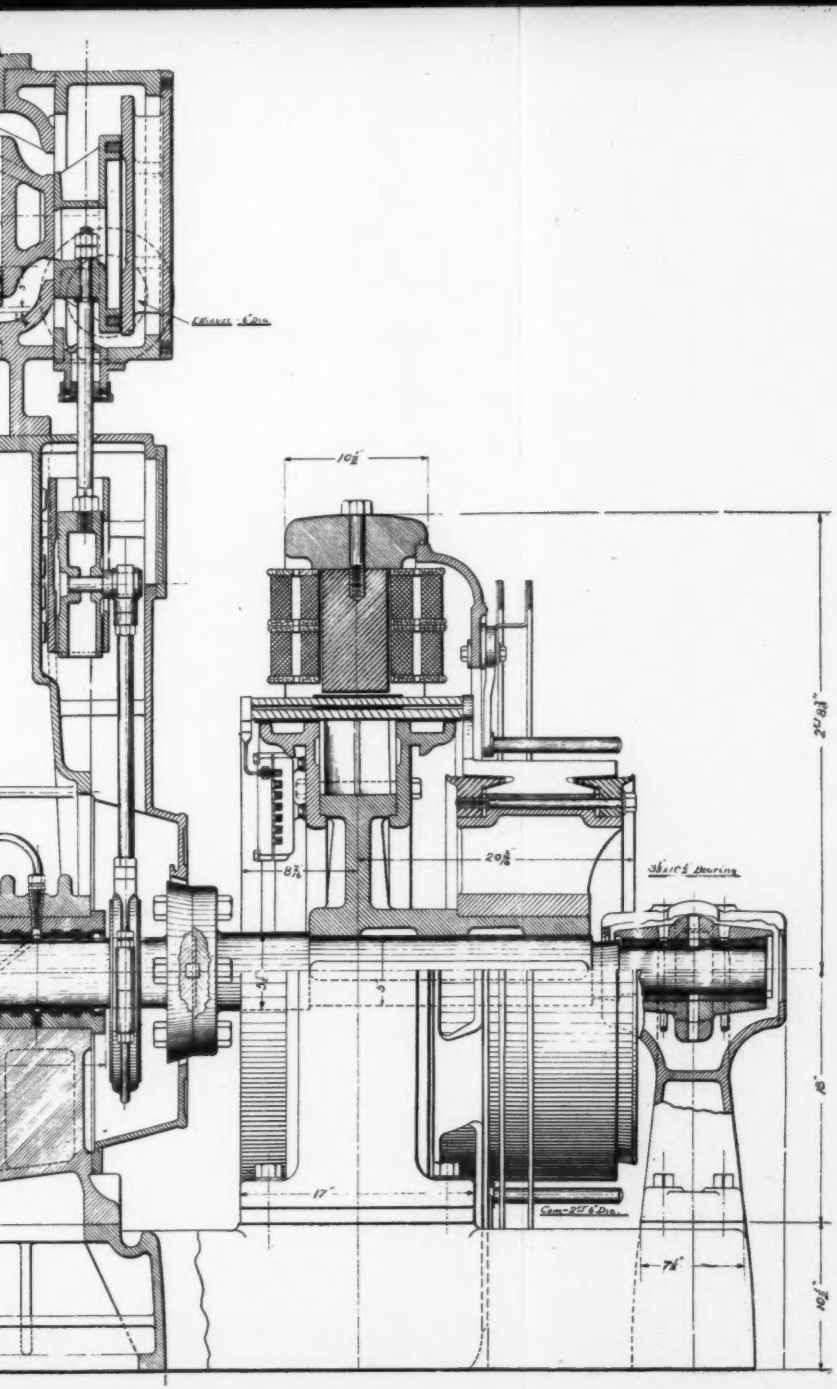
FOUR-CYLINDER TRIPLE-EXPANSION TWIN-SCREW ENGINES OF H. M. ARMORED CRUISER "DEFENCE," FITTED WITH FORCED LUBRICATION.
FRONT ELEVATION. OIL CASING OFF.



FOUR-CYLINDER TRIPLE-EXPANSION TWIN-SCREW ENGINES OF H. M. ARMORED CRUISER "DEFENCE," FITTED WITH FORCED LUBRICATION.
FRONT ELEVATION. OIL CASING OFF.



SECTION OF DYNAMO ENGINE FITTED FOR



TITTED FOR FORCED LUBRICATION.

Wherever used the verdict has been nothing but praise, the only regret expressed being that it was not adopted years before.

The question of economy is better appreciated when it is understood that with forced lubrication the oil is used over and over again and not wasted into the bilge after performing its function but once. In general, naval engines use about one gallon of oil per 100 I.H.P. per 24 hours. It is, therefore, obvious that the daily saving in oil for a large vessel having engines developing from 20,000 to 25,000 I.H.P. will be considerable. Several days' oil consumption would be sufficient to run a forced lubrication equipment for months.

The installation, as applied to large reciprocating marine engines, is not the simple arrangement as fitted to dynamo or blower engines, consisting of a small oil pump actuated by an eccentric on the crank shaft and a few pipes from same to the various bearings to be lubricated. In principle it is similar, but it involves much more gear and complications, rendering the lubricating system a plant in itself of no small moment, requiring skill and attention for its proper manipulation.

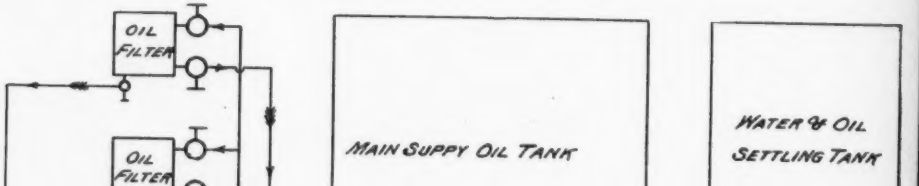
The following description of a typical installation is readily followed by reference to sketches as noted. In general the system consists of three steam oil pumps, one main-supply oil tank and one water and oil settling tank for each engine, together with the necessary piping, valves and filters, arranged as explained later. The crank pits are of oil-tight construction, fitted with an oil well, and are so designed that no bilge water or dirt can enter therein. An oil trough is thus formed at the base of each engine, to catch all the oil. The top of the crank pits are covered with a light sheet-iron casing to prevent splashing and waste of oil, but allowing sufficient clearance for the oscillation of the connecting and eccentric rods.

Designating the pumps as A, B and C (see Fig. 1), the pump A draws oil from the main supply tank and discharges same through oil filters to the main bearings only. The pump B is arranged primarily to draw oil from the crank-pit oil well and discharge same through filters to the main supply tank. The

filters are provided in triplicate, as shown, two intended to be used at a time, while the other is being overhauled and cleaned. This pump can also be used as an auxiliary on the water suction from oil well, with delivery to settling tank. The pump C is in the nature of a standby, principally intended to draw water and oil from the oil well and discharge same to the settling tank, but also arranged to perform the duties of both the other pumps in case of emergency.

The plant operates as follows (see Fig. 1): The pump A draws the oil from the main supply tank via pipe 1, and discharges same through pipe 7 and the filter to either main-bearing feed line 8. Branch pipes K (see Fig. 2) conduct the oil to the main bearings through the holes A in the bearing caps. The quantity of oil supplied is regulated by the stop valves 12. Annular grooves B distribute the oil throughout the main bearings and into the crank-shaft axial hole via the radial holes C, one to each journal, and thence via holes D to the crank-pin axial hole. The openings at the ends of axial holes are closed by oil-tight cover plates J. The crank pins are lubricated by the radial holes E, one for each pin, the annular grooves F distributing the oil to the bearing surface. Holes G are provided for supplying oil to the eccentrics. The crosshead pins are supplied by pipes 13 and swivel joints 15; thence through holes H to the brasses. Stop valves 14 are provided for regulating the flow of oil. A water-service supply pipe 16 is fitted to this connection, with drain 19 and 21 to bilge. Stop and check valves are fitted, permitting water alone or any combination of oil and water being supplied. All other parts of the engine are oiled in the usual manner, by gravity flow supplied from manifolds or cups. The crosshead pins are generally oiled in like manner, instead of being connected to the forced system. After performing its function, the oil is forced out at the ends of the bearings and drains to the crank pit, which, as previously explained, serves the purpose of a trough for catching the oil. From the crank-pit oil well the oil is drawn by the pump B (see Fig. 1) through the pipe 2 and delivered via pipe 4, oil filters and pipe 5 to the main supply

No	Service
1	Suction from Main Supply Tank
2	Oil suction from Oil Well



№	SERVICE
1	SUCTION FROM MAIN SUPPLY TANK
2	OIL SUCTION FROM OIL WELL
3	WATER " " " "
4	DISCHARGE TO FILTERS
5	" " MAIN SUPPLY TANK
6	" " WAT. & OIL SETTL'G TANK
7	" " MAIN BEARING OIL FILTRS
8	MAIN BEARING FEED LINE
9	DRAIN TO OIL WELL
10	" " BILGE
11	CROSS CONNECTION TO MAIN BEARINGS

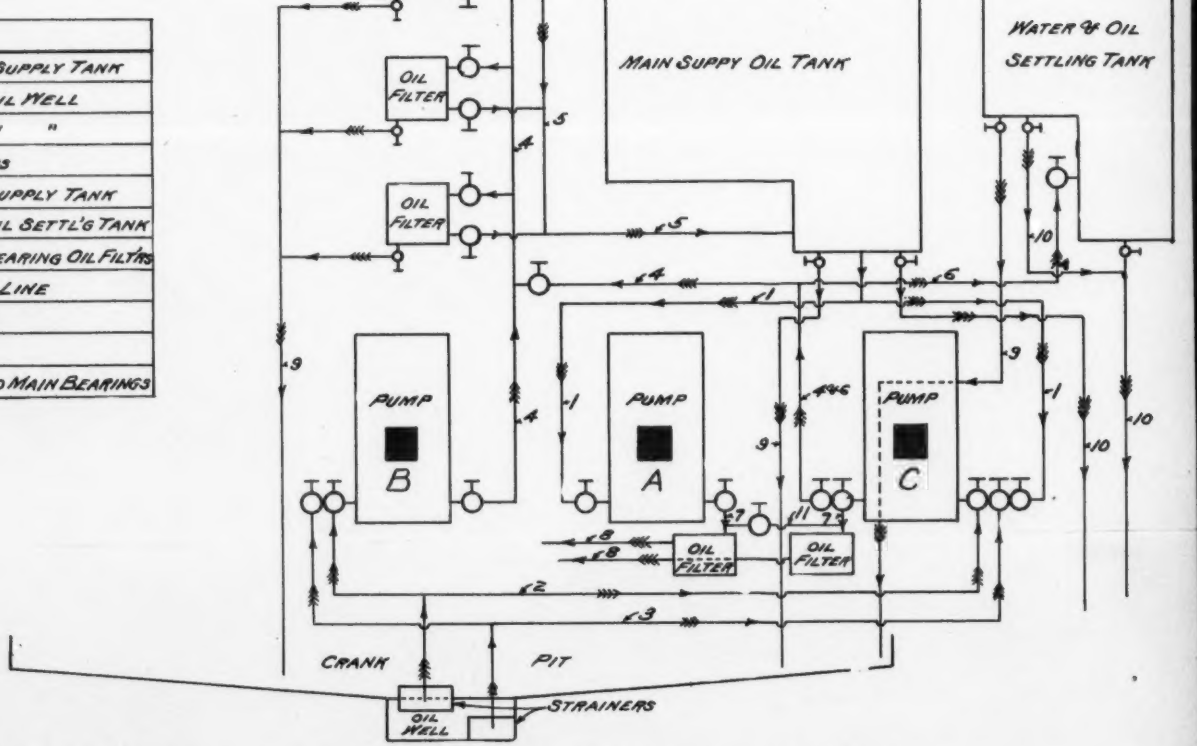


Fig. 1.—DIAGRAM SHOWING PIPING CONNECTION OF FORCED-LUBRICATION SYSTEM IN MAIN ENGINES.

№	SERVICE
8	MAIN BEARING FEED LINE
12	STOP VALVES, OIL TO MAIN BEARINGS
13	OIL TO CROSSHEAD PINS
14	STOP VALVES FOR SAME
15	SWIVEL JOINT " "
16	WATER SERVICE TO CROSSHEAD PINS
17	STOP VALVE FOR SAME
18	" " OIL FOR SAME
19	SWIVEL JOINT WATER SERVICE TO BILGE
20	STOP VALVE FOR SAME
21	WATER SERVICE TO BILGE
A	OIL TO MAIN BEARINGS
B	OIL GROOVE IN MAIN BEARINGS
C	OIL TO CRANK SHAFT AXIAL HOLE
D	" " " PIN " "
E	" " " " BEARING
F	" GROOVE IN CRANK PIN BEARING
G	" TO ECCENTRIC STRAPS
H	" " CROSSHEAD PINS
J	AXIAL HOLE COVERS
K	OIL TO MAIN BEARINGS

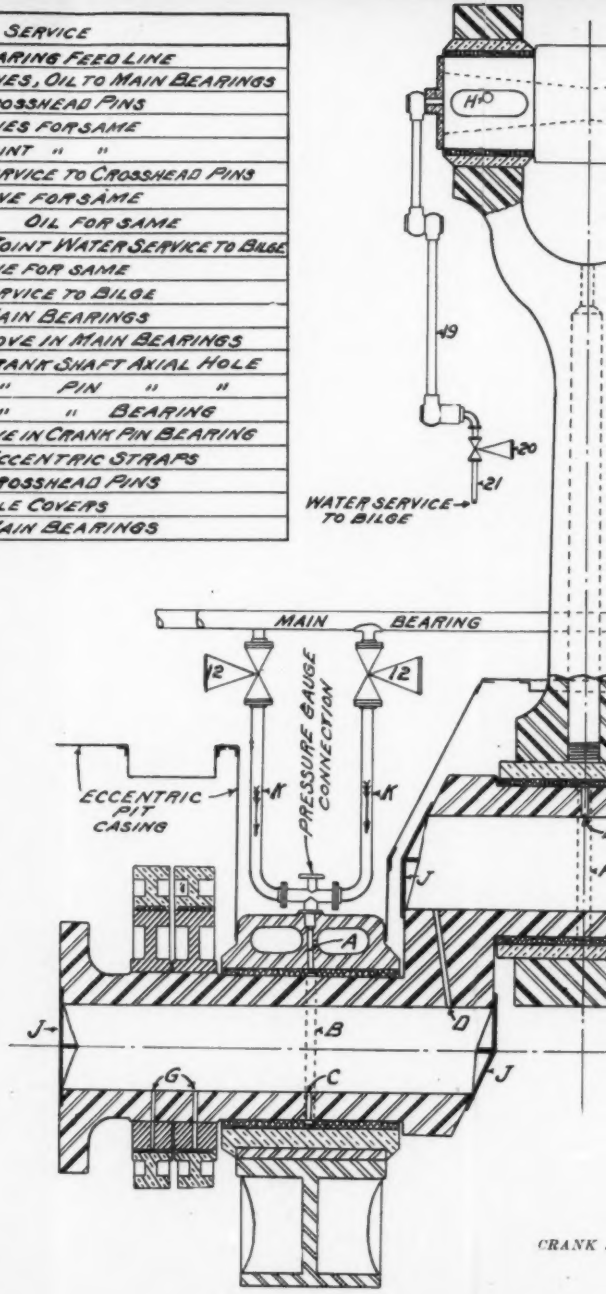
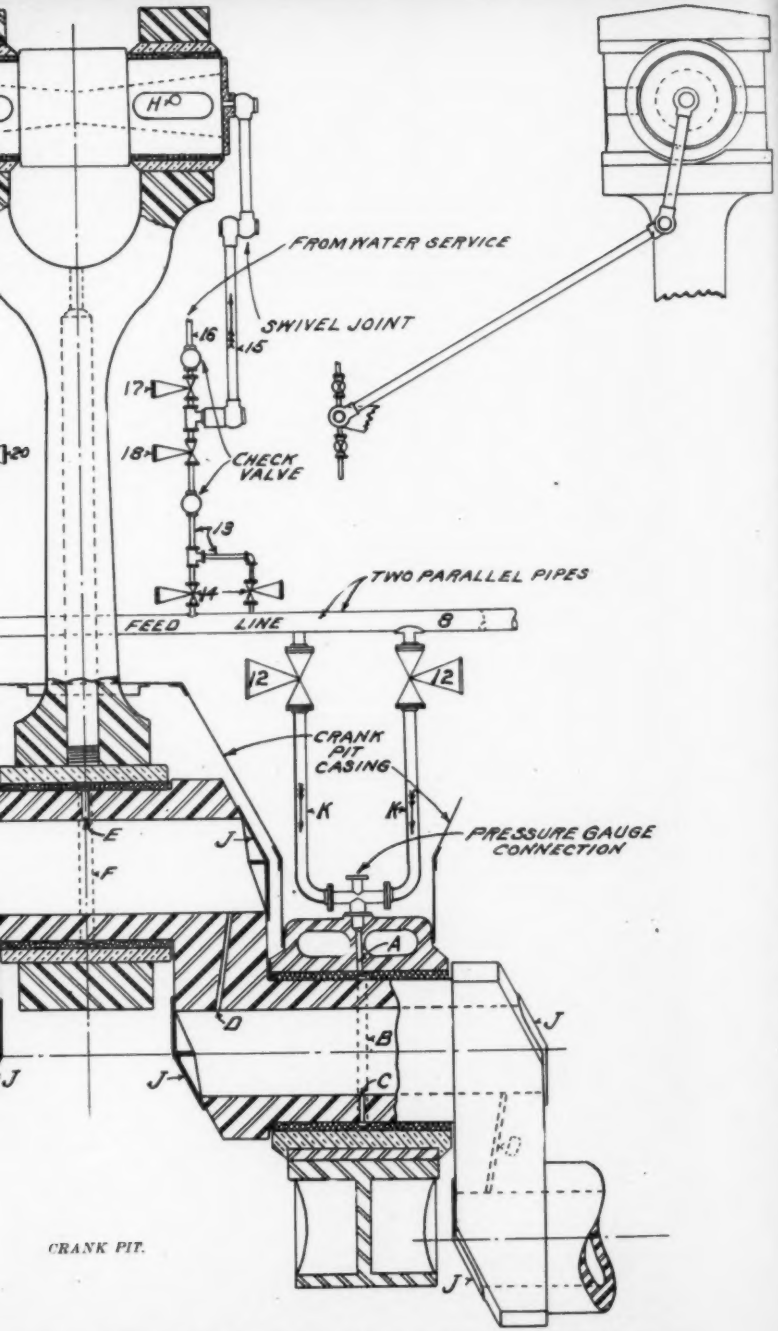


Fig. 2.—DIAGRAM SHOWING FORCED-LUBRICATION CONNECTIONS FOR



ECTIONS FOR CONNECTING ROD AND CRANK SHAFT OF MAIN ENGINES.

tank, thus completing its cycle, which is repeated indefinitely as described.

Should the oil show signs of water, due to water-service waste and other sources, the pump C is put on the water suction 3 from the oil well and discharges via pipes 4 and 6 to the settling tank, from which, after allowing to settle, the oil is drained off to the crank pit via pipe 9 and the water to the bilge via pipe 10. The settling tank connects to no pump suction.

Pressure gauges as indicated (see Fig. 2) show the pressure at which the oil is supplied. Thermometers are also fitted in the main bearing caps for taking the temperature of the bearings, etc.

Large storage oil tanks are provided for making up leakage and other waste and for replenishing the entire system when desired.

In using this system care must be taken that an oil that does not saponify and which does not leave a gummy residue is used. An oil that easily saponifies would, when brought in contact with water which will be present from small steam leakage along piston rods and the churning movement of the crank, cause a lather to form, which may in time stop up the oilways. Any gummy residue left by the oil, either in the bearings or oilways, would also stop up the pipes and prevent proper lubrication to some of the bearings. The strainers provided will guard against any dirt or mechanical impurities that may be left in the oil, but this does not guard against the saponifying or gumming action of the oil.

Special oils having the proper qualities for use with forced lubrication are supplied by the principal oil manufacturers.

The photographs of the engines of the British battleship *Defence* show the appearance of the oil casing around crank pits.

OIL FUEL FOR NAVAL USE.

By Lieutenant H. C. Dinger, U. S. N., Member.

Oil fuel has been used for marine installations for many years, and on vessels in proximity to the oil-producing districts it has been very extensively applied for marine use. Most of the older oil-fuel installations were fitted with burners in which the oil was pulverized or atomized by a spray or jet of steam or compressed air of high pressure. Of these the steam spray

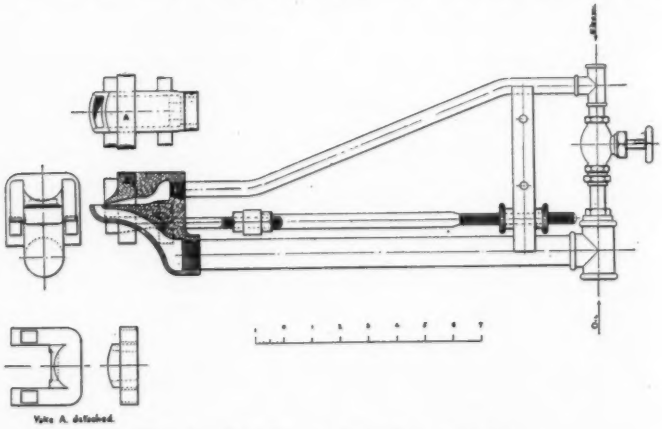


Fig. 1.—The W. N. Best Oil Burner.

was the most efficient. Among the burners of this type may be enumerated W. N. Best's, used extensively on locomotives employing oil of 10 pounds pressure; Hayes burner, using steam at 90 pounds pressure, oil at 10 pounds; the Branch burner, the Harvey burner, Oil City burner, Booth burner. The Rusden & Eeles and the Holden burner were used in England. The Gundell–Tucker burner employed air for

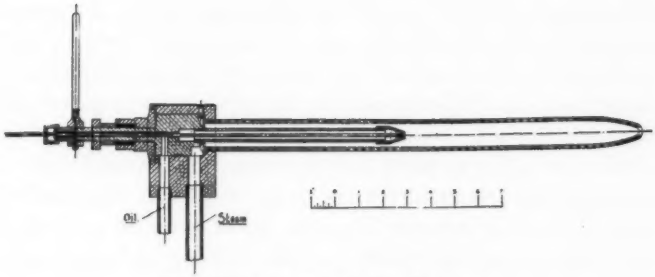


Fig. 2.—THE HAVES OIL BURNER.

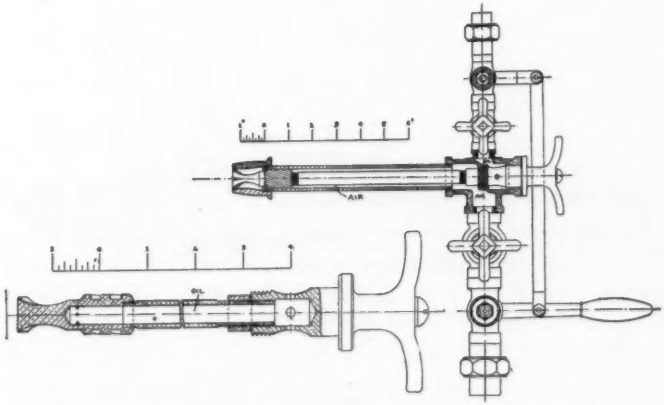


Fig. 3.—THE GRUNDEL-TUCKER BURNER USED ON STEAMSHIP "MARIPOSA."

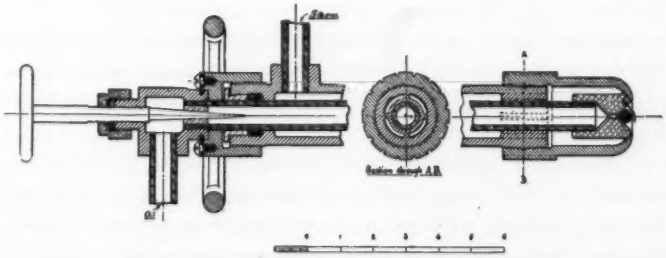


Fig. 4.—OIL CITY BOILER WORKS BURNER.

atomizing, air of 20 pounds pressure and oil at 40 pounds pressure being used in this case. These steam burners were successful in burning oil, but have the grave objection of requiring a very large amount of steam for atomizing the fuel. For marine work this expenditure of fresh water is a serious matter, and when as much as 5 per cent. of the steam produced was sometimes required for the spray, it is easily seen that for large powers the amount of extra water required is so great that this system was hardly possible for high-powered naval vessels.

Types of burners are illustrated in the figures 1–5.

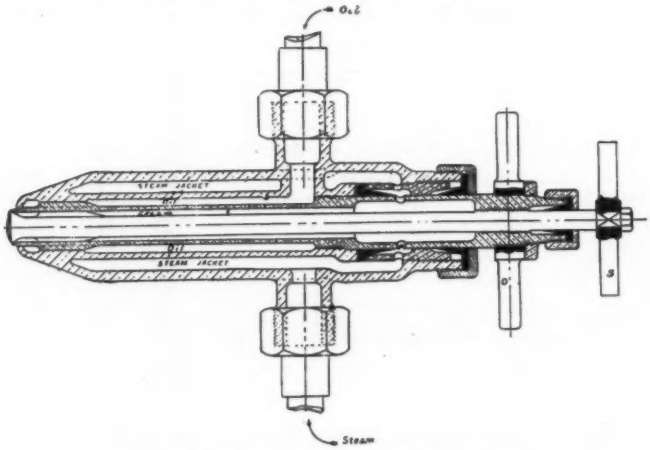


Fig. 5.—THE RUSDEN AND EELES BURNER.

Those systems using high-pressure compressed air often necessitated large and cumbersome air compressors and often did not produce as satisfactory combustion as the steam spray.

In the atomizing system it is found to be advisable to superheat the syraying medium.

There have, however, been in use several systems of air-atomizing or spraying burners which use what may be termed low air pressure, such as can be delivered by a rotary blower. Among these systems is the Lassoe–Lovekin system, fitted on the following steamers:

	Displacement.		Displacement.
Tenyo,	21,650	*Lurline,*	12,000
Chio Maru,	21,650	*Texas,*	11,200
Virginian,	18,000	*Santa Rita,*	10,800
Mexican,	18,000	*Santa Maria,*	10,800
Missourian,	18,000	*Isthmian,*	10,700
Columbian,	18,000	*Lansing,*	10,200
Texan,	17,800	*Nevadan,*	8,800
Alaskan,	17,600	*Nebraskan,*	8,800
Arizonan,	17,600	*Cacique,*	7,200
Oklahoma,	12,700	*Washtenaw,*	7,000

The air used for atomizing is furnished by a Wilbraham–Green or Root's type of rotary blower driven by a direct-connected steam engine. The air pressure at the discharge of the blower is from 1½ to 2 pounds, and the corresponding oil pressure at the discharge of the oil heater is from 15 to 20 pounds. The vessels that are equipped with the air system are also provided with a complete set of steam burners and the necessary steam piping, so that in the event of the blower breaking down the ship can complete the voyage using the steam burners. The S. S. *Washtenaw,* a cut of which is shown Figs. 6 and 7, is fitted with both the air and steam burners. The air-atomizing system is more economical, but the weight of blowers and air ducts is objectionable in some cases, as torpedo and other war vessels.

With steam atomizing the oil pressure is from 75 to 100 pounds, and the corresponding steam pressure a little below that of the oil. The steam atomizing system, though not so economical, gives, nevertheless, excellent results, only the amount of steam used for atomizing is objectionable.

A recent installation of this system on the S. S. *Isthmian* is shown in cut, Figs. 8–10.

With this system, that of steam atomizing, the steam used has been cut down to as small as 2 per cent. of the water evaporated. Experience with this system shows a gain of fully 20 per cent. in the boiler power by using oil instead of coal; also that the boiler repairs are reduced.

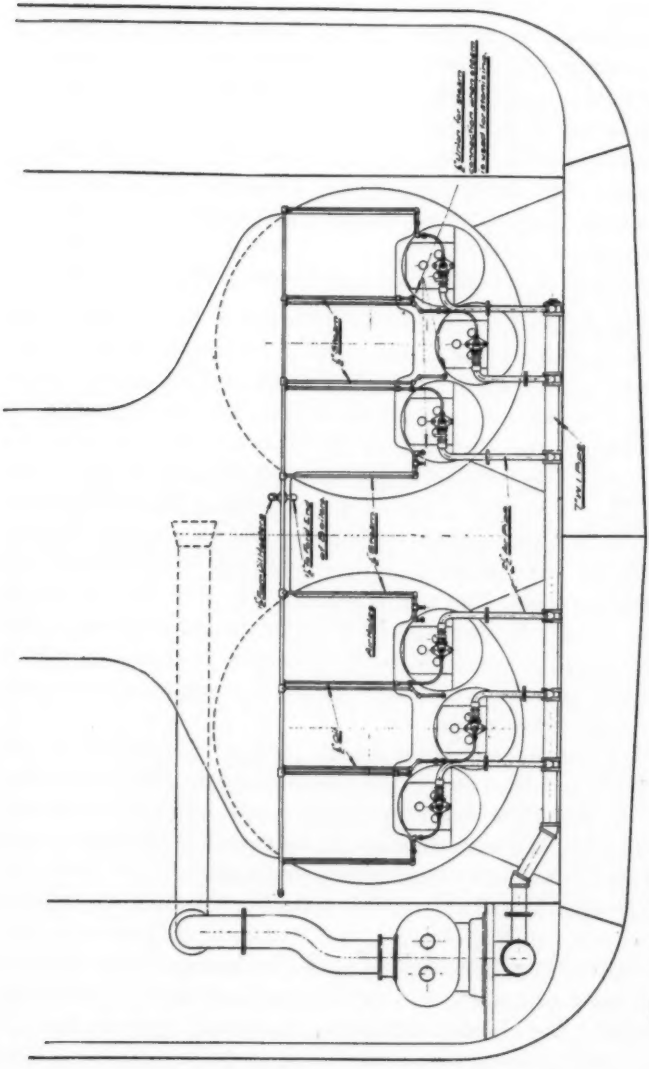


Fig. 6.—Lässoe-Lovekin Air and Steam Atomizing System as Fitted on S. S. "Washtenaw."

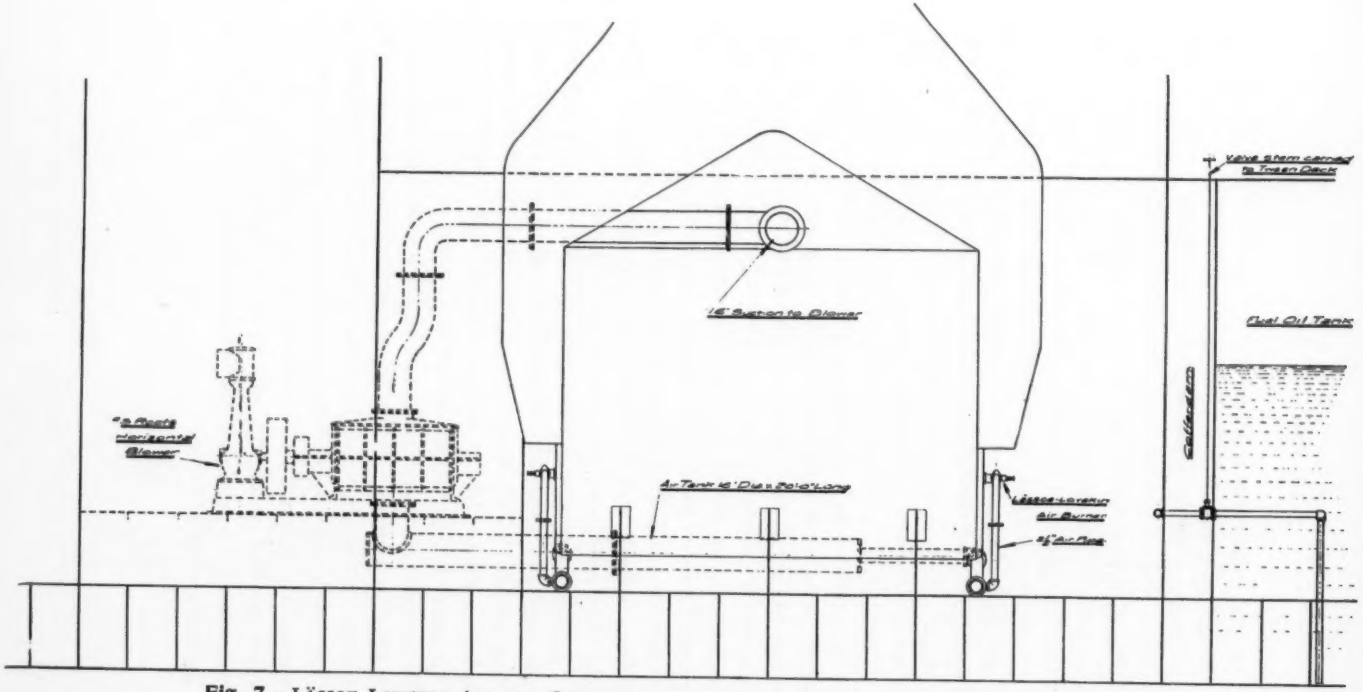

Valve Steam operated by Time on Deck
16" Suction to Blower
Fuel Oil Tank
Collectors
Air Tank 16" Dia x 20'10" Long
Lässoe-Lovekin Air Burner
4" Air Pipe

Fig. 7.—LÄSSOE-LOVEKIN AIR AND STEAM ATOMIZING SYSTEM AS FITTED ON S. S. "WASHTENAW."

A very steady steam pressure is given, the boiler gauge not varying more than 1 to 2 pounds in a continuous run of over fifty days, whereas with coal the fluctuation of the steam pressure is considerable on account of cleaning fires, etc.

The Howden system has been very successful in connection with fuel-oil installation on merchant vessels. Howden draft with oil fuel has this advantage over natural draft: that no cold air is admitted at any time during the whole run, as the furnace doors and uptake doors are closed, and tubes need not be cleaned, so that the temperature remains even throughout the voyage. This system has been in successful use in the merchant service, and is at present in use to a considerable extent.

The objections of loss of fresh water and the employment of heavy pressure air compressors or blowers being present in the steam or high-pressure oil-atomizing installations, efforts were made to develop a system, relying neither on steam or high-pressure air for securing vaporization. This system is now successfully developed in various parts of the world and is in general known as the mechanical oil-burning system. The widely known Koerting system, Kermode system, and what is known as the British Admiralty system, are of this type. There are other systems of this type less well known.

In this system the oil (which should have a flash point about 180 degrees Fahrenheit) is heated by means of steam in a surface heater to well above its flash point, and is forced under heavy pressure, 100 to 200 pounds, through a spiral sprayer. Air under low pressure, ½ inch to 5 inches of water, is forced in around the burner, and as the oil leaves the burner it is gasified and ignites, the air being supplied to produce the combustion. The air is usually deflected by a system of deflecting plates or vanes so as to have a spiral or whirling movement, which, together with the spiral oil spray, enables a very intimate mixture of oil gas and air to be made. The mixture, when properly regulated, enables an almost perfect and smokeless flame to be produced.

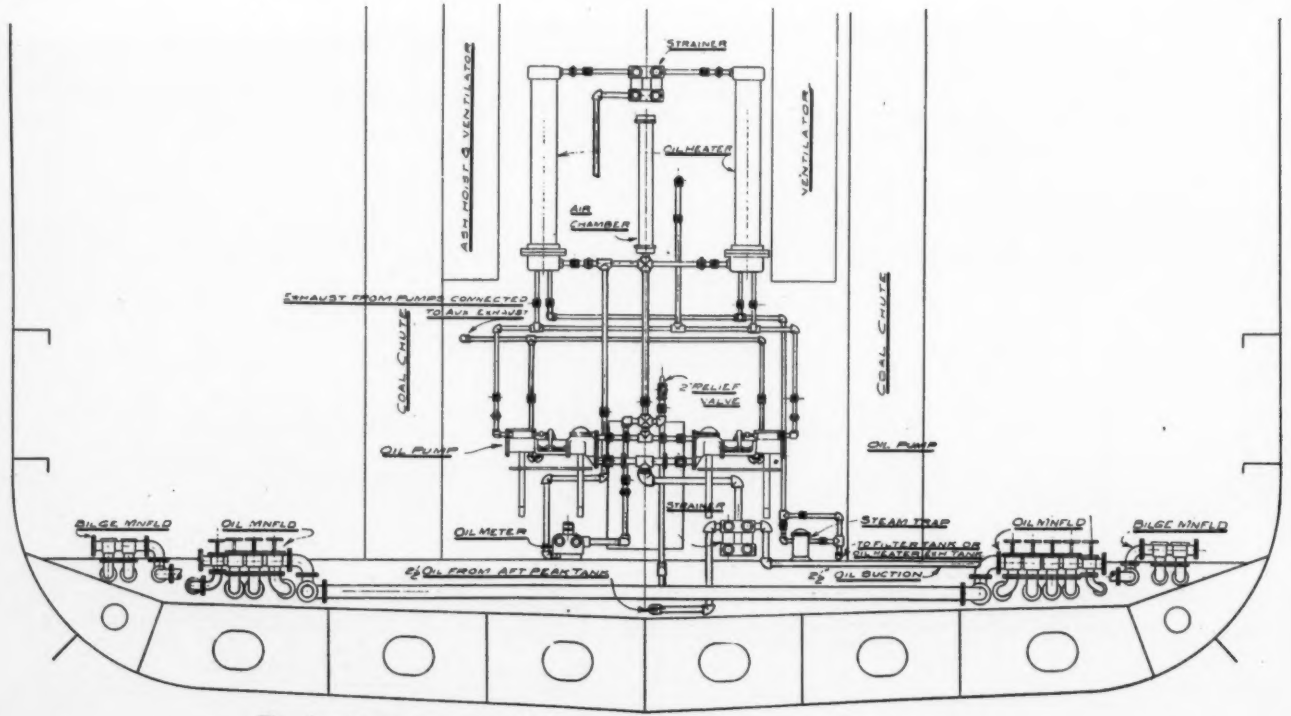


Fig. 8.—Arrangement of Oil Fuel Piping Connections, S. S. "Isthmian."

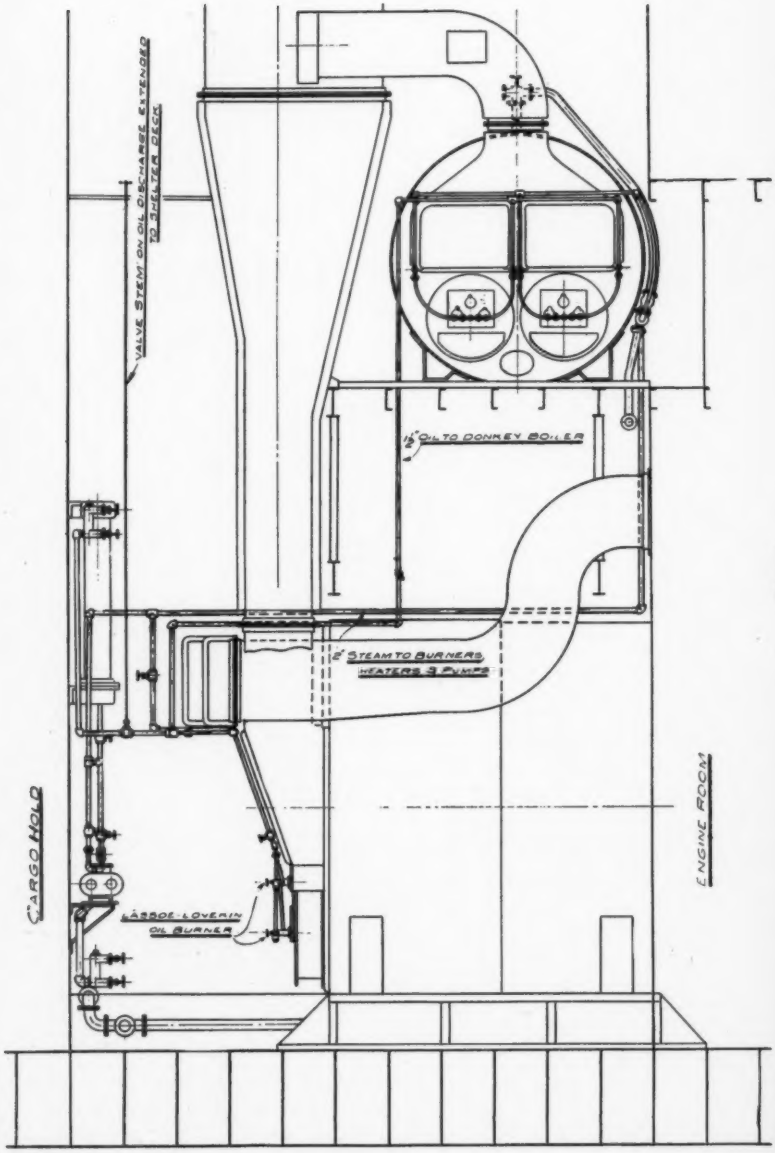

VALVE STEM ON OIL DISCHARGE EXTENDED TO SHELTER DECK
1½" OIL TO DONKEY BOILER
1" STEAM TO BURNERS HEATERS & PUMPS
CARGO HOLD
ENGINE ROOM
LASSOE LOVERIN OIL BURNER

Fig. 9.

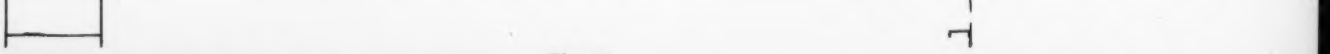


Fig. 9.

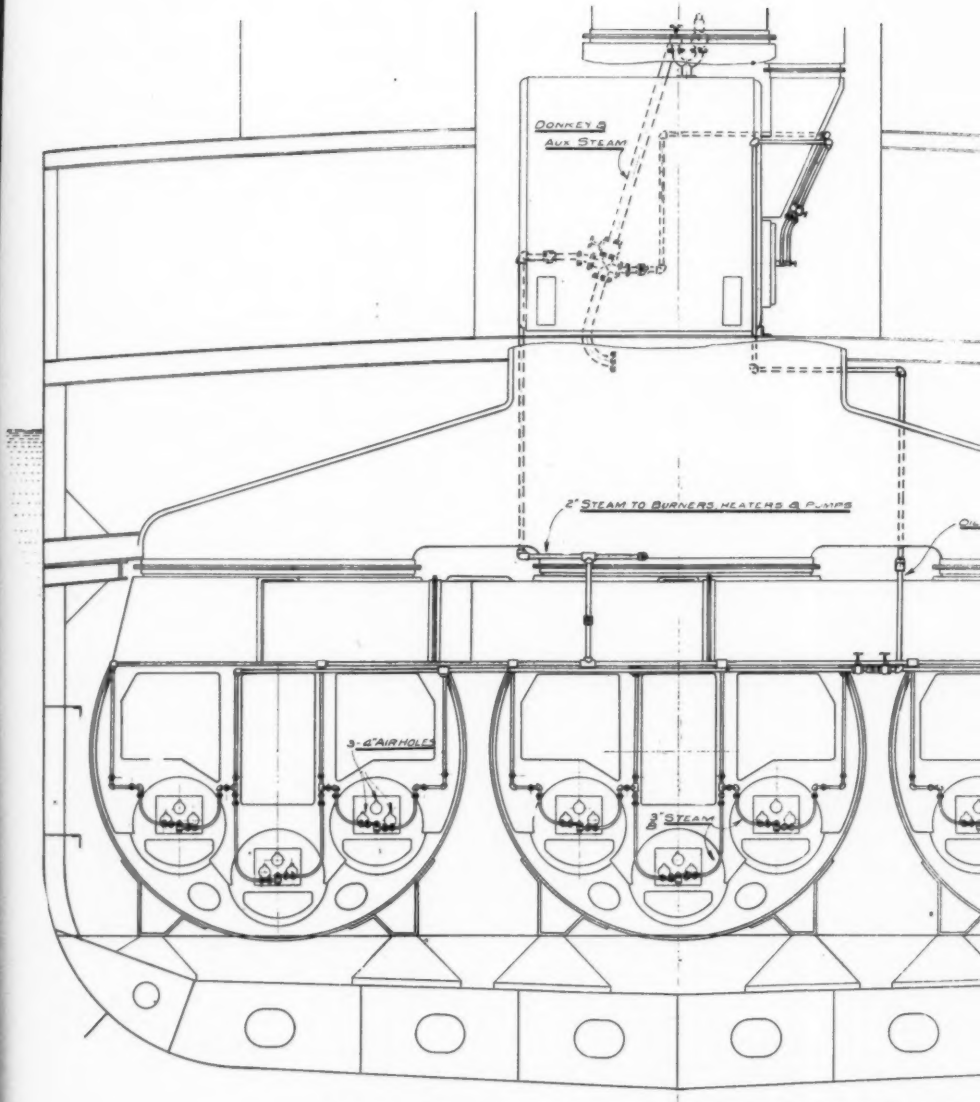
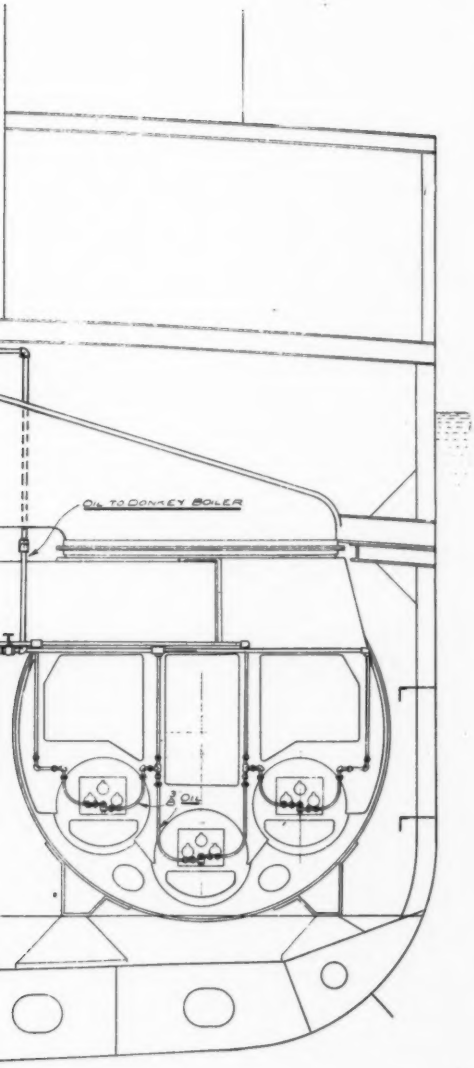


Fig. 10.—Lässoe-Lovekin Steam Atomizing System, S. S. "Isthm



S. "ISTHMIAN."

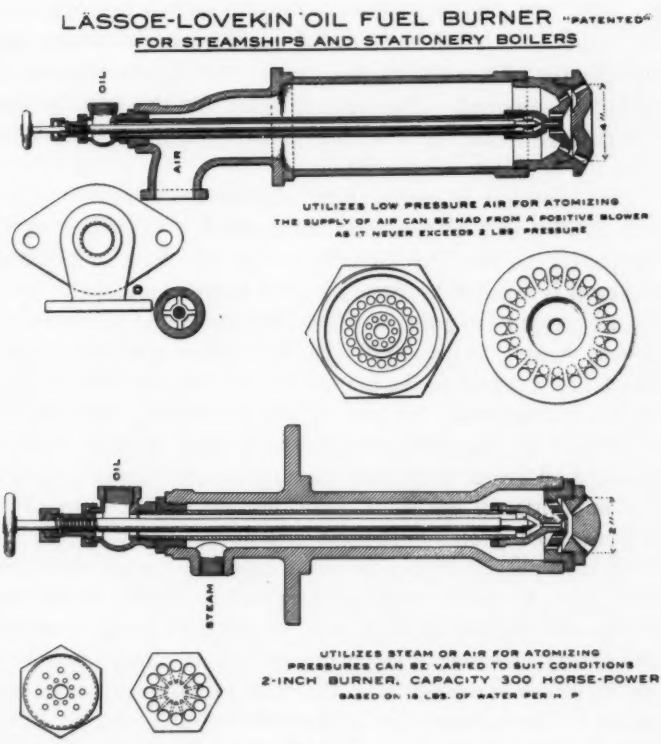

LÄSSOE-LOVEKIN OIL FUEL BURNER "PATENTED"
FOR STEAMSHIPS AND STATIONERY BOILERS
OIL
AIR
UTILIZES LOW PRESSURE AIR FOR ATOMIZING
THE SUPPLY OF AIR CAN BE HAD FROM A POSITIVE BLOWER
AS IT NEVER EXCEEDS 2 LBS PRESSURE
OIL
STEAM
UTILIZES STEAM OR AIR FOR ATOMIZING
PRESSURES CAN BE VARIED TO SUIT CONDITIONS
2-INCH BURNER, CAPACITY 300 HORSE-POWER
BASED ON 18 LBS. OF WATER PER H. P.

Fig. 11.

GENERAL DESCRIPTION OF MECHANICAL SYSTEM.

The oil is stowed in the fuel-storage tanks, these being double-bottom compartments other than those under the fire-rooms. From these tanks the oil is pumped by means of a low-pressure oil-supply pump to the *settling tanks.* The purpose of the settling tank is to effect the separation of any water that may be contained in the oil. The settling tanks are usually fitted in duplicate, so that the process of separation may be taking place in one tank while the other is being used to supply the burners. The settling tank contains a heater coil and a drain for drawing off the water that collects at the bottom of

the tank. The heating of the oil facilitates the separation of the water, and it has been found that in order to effectively separate the oil a temperature of about 180 degrees Fahrenheit should be obtained. The heating agent for the settling-tank coil may be either the auxiliary exhaust steam or live steam from the auxiliary steam pipe.

The operation of settling tank is generally as follows: The tank is filled with oil from the storage tank. (It is best to fill completely, so that any disturbance due to rolling or pitching of vessel is avoided.) Steam is then turned on and the heating and separation goes on. The heating should be continued several hours. After separation has taken place the water which has collected at the bottom of the tank is drawn off and the oil is then ready for use. From the settling tank the oil is pumped by the heavy-pressure oil pumps through a high-pressure oil heater to the burners. In order to guard against any impurities in the oil clogging burners the oil is made to flow through duplex wire-mesh strainers. The strainers are fitted in duplicate, so that one may be cleaned while the other is in use. Strainers are often fitted on both suction and discharge side of the fuel-oil pumps. In the high-pressure heater, which may be either of the ordinary surface-tubular type or a special heater of the film type, the oil is heated by means of live steam to the temperature at which it is to be burnt. This temperature will vary from 150 degrees to 300 degrees Fahrenheit. The pressure of the oil as delivered to the burners may also be variable and can be adjusted in reference to the temperature at the point which will give the best results. The pressure of the oil may vary from 50 to 250 pounds per square inch.

After leaving the pressure heater the oil is discharged (through strainers generally) to the burners located in the furnace front. The amount of opening to burners is regulated by a cock or valve, which regulation is in addition to that obtained by changing the pressure of the oil.

A section of a burner is shown. The revolving spray is given to the oil by the spiral cut on the spool at tip of burner,

and the air to support combustion is drawn in around the burner, and is usually deflected so as to give it a whirling movement in order to obtain a better mixture with the gasified oil.

The air may be under natural or forced draft, and the highest air pressure employed is not above 5 inches of water.

The capacity of a burner depends upon its size, varying from 200 to 700 pounds of oil per hour. Burners can be built capable of burning 800 pounds of oil per hour, with an air

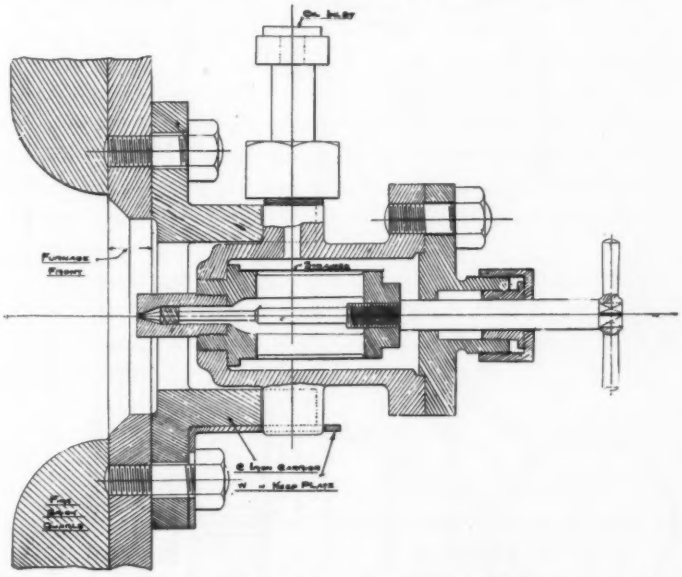


Fig. 12.—Section of Korrting Burner.

pressure of about four inches of water. With natural draft such burner would burn only about one-half of this amount.

The actual evaporation of water per pound of coal will vary from about 14 to 16, as against 8 to 11 for coal. Better results will be obtained with lower rates of combustion in about the same manner as with coal.

In order to adjust the amount of air for the rate of combus-

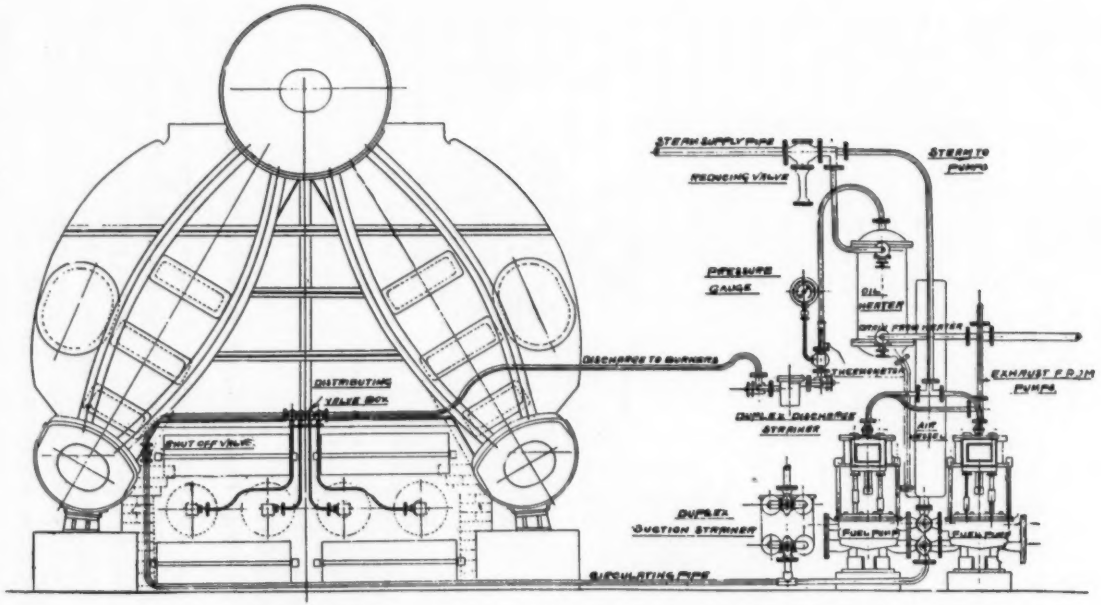


Fig. 13.—KOERTING SYSTEM AS APPLIED TO THORNYCROFT BOILER.

Diagram reproduced from Mr. Laing's Article on Oil Fuel, "Cassier's Magazine," November, 1908.

tion special shutters or damper doors are fitted in the furnace front, and by regulating the opening the amount of air desired may be secured. The air can also be regulated by changing the speed of the blowers, which will, of course, affect the air pressure.

COMPARISONS, COAL VERSUS OIL.

A pound of good steam coal will contain 13,500 to 14,500 B.T.U., a pound of fuel oil 18,000 to 20,000 B.T.U. Therefore, for an equal weight of fuel the oil contains about 35 per cent. more heating value than does coal. Moreover, as fired in marine boilers, coal is never all burnt, since there is considerable loss in the ashes and in incomplete combustion, due largely to improper air supply and defective firing. On account of this, in actual practice, with efficient burners, a ton of oil is equal to about 1¾ tons of coal. The report of the United States Liquid Fuel Board, 1904, placed the relative evaporative value of oil to coal per unit weight at 18 to 10.

Thus, with a limited weight allowed for fuel, you can get about 1¾ times as much out of oil as out of coal. This fact gives to oil an immense advantage as a fuel for naval vessels where weight is a matter of such great import.

RELATIVE COST.

The question of relative cost may next be considered. The cost of steaming coal of good quality varies very greatly in different parts of the world. On the Atlantic coast it may be secured for about $3.00 a ton; in England and Europe at $3.50 to $4.50; in the Mediterranean and along the route of the Suez Canal at $5.00 to $6.00; in China and Japan at $6.00 to $7.00; on the west coast of North America $7.00 to $10.00; while at South American ports as much as $20.00 a ton has been paid.

Coal along trade routes will cost from .13 to .4 cent a pound.

The present price of fuel oil at commercial points, when bought in large quantities, is as follows:

	Cents per gallon.		Cents per gallon.
Key West, Fla.,	3.00	Hawaii,	4.00
Norfolk, Va.,	2.75	Manila,	4.00
New York, N. Y.,	2.50	Hong Kong,	4.72
Boston, Mass.,	2.50	Yokohama,	4.11
Philadelphia, Pa.,	2.25	Port Said,	4.28
San Francisco, Cal.,	2.38	London,	3.71
Seattle, Wash.,	2.75	Liverpool,	3.71

The price thus varies from .3 cent to .6 cent per pound. In order to compete with coal on the basis of price per evaporative power oil would have to be sold for one and three-quarter times the price of coal. Along the Atlantic coast this would have to be at about .23 cent per pound, or about 1.8 cents per gallon. However, as the cost of handling is considerably less with oil than with coal, and as the cost of firing oil is very much less, the cost of oil might be yet higher than this and still have the advantage. It will cost about 25 cents per ton more to fire coal than to fire oil, and considering that there is less loss in getting underway and shutting down, taking fuel on board, etc., it might be considered that conditions are even as to price, when oil costs twice as much as coal per weight.

In all places where oil is relatively cheaper than this proportion oil burning would be profitable on the score of cost of fuel and labor of handling it.

In view of the prevailing prices of oil and coal it is easily seen that oil has the advantage in numerous parts of the world, such as the Gulf of Mexico, California coast, Black Sea and environs.

Other considerations of cost are:

(a) First cost of oil installation *in the boiler room* is, perhaps, somewhat more than would be required for the coal-burning apparatus. Since there are required the burners, oil pumps, heaters, settling tanks and piping, this could cost considerably more than the grates and firing tools. On the other hand, costly ash ejectors, ash hoists, firing indicators, coal buckets, shovels and all coaling gear are done away with, not to say anything of the fittings of the coal bunkers. However,

as the fuel-oil tanks require closer riveting and special means for ventilating and cleaning them, it is doubtful whether the fuel tanks and their necessary accessories and safety devices would cost less than coal bunkers for the same fuel capacity. As to the question of cost of installation, we then have the ash ejectors and hoists, grates, fire tools, coal and ash buckets, coal bags and all deck-coaling gear, including special coaling booms, winches, etc., balanced against the oil-burning apparatus, consisting of the burners, heaters, pumps, settling tanks and piping. An approximate estimate would place the difference for a battleship at about $5,000 to $10,000 in favor of the oil-burning apparatus. The total difference in weight would be about forty tons in favor of oil-burning apparatus. The difference in weight and cost of installation are thus not very great.

(b) When it comes to the question of repairs and wear and tear, the oil system has special advantages, since there is little in the oil-burning apparatus that is likely to wear out or require considerable repair. There are no grate bars to burn out, no fire tools to repair, or ash-handling machinery to keep in order.

The oil tanks, when once fitted, will require practically no repairs, while coal bunkers need constant care and attention, requiring repeated cleaning, scaling and painting, etc.

The oil-burning system will also bring less wear on the boilers, since the evaporation is more uniform, and, being rid of coal, ashes and also bilge water in firerooms, there is much less danger of corrosion and deterioration due to dirt, moisture, etc.

It is thus seen that under conditions now prevailing and likely to prevail for some time fuel oil has advantages in cheapness, in places where it can be obtained at a cost per pound not more than twice that of coal.

OTHER ADVANTAGES OF OIL FUEL.

For commercial purposes the question of burning oil or coal is mainly a question of the relative cost in the locality in which a certain vessel operates. But in the case of naval vessels there are other material considerations besides the cost of fuel. In

a man-of-war, aside from the money saving, it is very important to reduce the number of men required to operate the machinery; to reduce the weight of fuel required for a certain steaming radius; to reduce the space required for the fuel; to reduce space and weight of boiler installation; to increase the facility and ease with which a new supply of fuel can be received. The ability to produce rapid changes in the rate of evaporation and the ability to maintain a constant uniform rate of evaporation are likewise of paramount importance.

Taking each of these points separately—

Reduction in Number of Men.—With oil-burning apparatus only about one-third of the fireroom force need be carried. However, on a man-of-war, owing to the fact that the ship's force does most of the routine repairs, such a reduction would not be possible, but the fireroom force could, perhaps, be reduced one-half if boilers were fired with oil instead of coal. On a battleship this would mean a reduction of about eighty men. Incidentally, it would mean a reduction in berthing space, food carried and other matters of accommodation for these men, including reduction in storerooms, washrooms, boats carried, cooks, police force, etc., so that this saving would really be represented by much more than the wages of these 80 men, since weight, space and general accommodations would be reduced.

Reduction in Weight and Space of Fuel.—Coal *as stowed* occupies about 45 cubic feet to the ton, while oil occupies only 38 cubic feet to the ton. There is thus a material saving in space. Furthermore, the oil can, to a large extent, be stowed in the double-bottom compartments not otherwise used, so that in reality the oil will occupy but little space that might be useful for other purposes. For equivalent evaporative capacity the dead weight of fuel carried can be reduced about 40 per cent. This on a large battleship is about 4 per cent. of the total displacement; on a destroyer about 10 per cent.; on a scout cruiser 16 per cent. This reduction in weight can, of course, be used to increase the steaming radius the corresponding amount, or the weight put into increased power, battery or armor.

Uniform Steaming and Control of Rate of Evaporation.—Oil-burning boilers have the advantage in that the rate of evaporation is easily and absolutely controlled, and absolute uniformity in this matter can be secured.

The regulation of the rate of evaporation simply becomes the question of increasing the supply or pressure of oil to the burners or of shutting off or starting some of them. An oil-burning installation can thus be much more sensitive to any sudden change in power.

With coal-burning apparatus there is a considerable amount of energy in the bed of fuel on the grates. This cannot be suddenly increased or decreased. Changes in the steam power of this bed of fuel can only be made gradually and by more or less indirect methods, such as starting and stopping blowers, putting ash pans on and off, building up fires or letting them burn down. In the case of oil, the full heating capacity of the burner is obtained in a few minutes, and it can be stopped or diminished quickly. Also on this account the loss of heat caused in starting fires and letting them die out is greatly diminished.

With oil there is no irregularity in evaporation due to such bugbears as cleaning fires or hoisting ashes, or troubles in getting coal from distant and remote bunkers. The maximum evaporative capacity of the boiler can be kept up *every minute of the time,* so that the average power should be considerably greater with oil fuel than with coal, though the boilers were the same. This, of course, means a higher sustained speed for the ship with the same boiler weight. The sustained full power for same boilers may be taken at about 20 per cent. more with oil than with coal.

Ease of Taking Fuel on Board.—With oil fuel the difficulties and harassing inconvenience of coaling ship are obviated. The oil is simply pumped on board, and there is thus no more trouble than in taking water on board. Special coaling winches, coaling booms, hoists, etc., will not be needed and the original expense and wear and tear of this apparatus is saved.

Moreover, a supply of fuel oil can be taken from a fuel car-

rier at sea without any of the great trouble that attends the transfer of coal. Likewise a supply can be easily transferred from one naval vessel to another. With coal it is practically impossible for men-of-war, owing to the trouble of getting the coal out of the ships' bunkers.

This last point is of immense military advantage, since this would enable a fleet of vessels to steam the farthest distance that their *combined* fuel would allow. With coal the fleet is limited to the vessel having the *least* supply.

Reduction in Weight and Spares.—With coal firing, large quantities of grate bars, firing tools, coal and ash buckets, coaling bags, coaling booms, trucks, chutes, coal winches, ash-hoisting and ejecting machinery, etc., have to be carried. Against this there is the oil-burning apparatus, consisting of the oil pumps, piping, heaters, and the burners and their special accessories. For an installation of 20,000 I.H.P. the accessories for the oil-burning apparatus would weigh about forty tons less than the accessories for the coal-burning apparatus.

DISADVANTAGES OF OIL FUEL.

Having spoken of the advantages, it will now be proper to speak of the disadvantages and objections which also exist.

STOWAGE OF OIL.

The safe stowage of oil on board of a man-of-war requires a number of considerations, some of which may be neglected in the merchant marine.

1. The oil should be stowed well down in the vessel, where puncture of the oil compartment is well guarded against. Consequently all the oil must be stowed well below the water line.

2. The stowage should be such as to avoid a flow of oil into the firerooms in case any compartment may be ruptured or broken. This requirement prevents the use of bunker spaces directly on the sides of the boiler rooms, and also the double bottoms under the firerooms.

3. Special ventilation and arrangements for drawing off the gas generated by the oil fuel must be provided.

4. The stowage space must be properly riveted to hold the oil. This requires a close spacing of rivets and more careful caulking than is usually used for bunkers or double bottoms.

5. If oil is used exclusively, the natural protection afforded by coal in bunkers is entirely lost. This protection is, of course, only incidental, since a vessel may have to fight with bunkers nearly empty, but the problematic advantage of coal protection is a material advantage, and in summing up the case of Oil versus Coal it should be given its due weight.

In view of the above, the spaces available for stowage of oil are practically restricted to the double-bottom compartments other than those abreast and under the boiler rooms. On a first-class battleship these available spaces would give a capacity of about 1,000 tons of oil. This capacity could be increased by increasing the depth of the double-bottom compartments so that it would be possible to get a capacity of something like 1,200 tons of oil in a large battleship.

DANGERS DUE TO OIL ON BOARD A MAN-OF-WAR.

The danger for oil-burning systems may be placed in two general classes:

(1) That due to the formation of explosive gases in the oil tanks when partially empty and not properly ventilated.

(2) Danger from hot oil or gasified oil escaping into the firerooms through leaks and catching fire.

The first may be guarded against by a proper system of ventilation which will allow explosive gases to be led off, and by proper cleansing of the tanks when they are empty.

The following remarks on tank ventilation are taken from the report of the Liquid Fuel Board, page 372:

"In the storage of fuel oil on shipboard it is of the highest importance not only that the most careful attention should be devoted to the method and quality of riveting, to secure oil-tightness of bunkers and double bottoms, but that great care should be exercised in the design of the oil-tank ventilation devices. It is well known that all crude oil generates more or

less vapor of an explosive nature, and this vapor, being heavier than the air, rests upon the top of the oil in tanks or bunkers.

"This vapor can be removed by natural or artificial means, but as the formation of the vapor from a tank of oil proceeds rather slowly, it is usually found that a system of natural ventilation can be devised so that sufficient of the vapor can be easily removed.

"All ventilating leads or cowls should proceed as direct as possible to weather decks, but should be located not too near the smokestack. In all circumstances the oil-ventilating cowls should be fitted with wire gauze, soldered into the cowl opening.

"This wire gauze permits easy exit of vapor, while preventing any back flash into the vapor pipe from a stray spark from the main funnel or a light from a careless smoker on deck.

"These oil-ventilation cowls from their very exposed positions are often caught by the rush of heavy shipped seas, and salt water is likely to pour down into them. Hence it is desirable to goose-neck these cowl pipes, as is often done on board torpedo-boat ventilator pipes, or to design a cowl pipe with a light ball float, which will close under the pressure of water in the manner of a check valve."

The following remarks are taken from "Warship Engineering," by C. DeGrave Sells:

"Several minor mishaps have occurred from compartments which had contained the oil being entered with a naked light, so special regulations are now being enforced as to the precautions to be observed before the men are allowed to enter any compartment which has contained liquid fuel.

"When a compartment is emptied as far as possible by the liquid-fuel pumps, any residue is to be pumped out by hand pumps. The compartment is then to be filled with sea water through the oil-filling pipes, so as to expel any gas remaining, and to assist in cleansing the compartment from any accumulations of thick residue, and this operation is to be repeated as often as considered necessary. It is finally to be pumped out as dry as possible, and all the surfaces well cleaned of any remains of the oil, and until then no naked lights whatever are

to be allowed in the compartment, only safety lamps or portable electric lamps being used."

Another method proposed for clearing oil tanks of the explosive vapor is to provide a steam connection. If steam is turned on it will drive the oil vapor out of the vent and will then condense and leave the compartment clear of the dangerous gas.

The second class of accident is due to either a leak from the oil tanks into the firerooms or from leaks in the oil piping or oil-burning apparatus.

One of the most frightful accidents of this kind took place on the German battleship *Kaiser Friedrick III,* in April, 1901. The vessel struck a rock and fractured the inner bottom under firerooms, where oil fuel was stowed. The oil ran into the fireroom and caught fire, causing disastrous results to the personnel as well as machinery.

One of the worst accidents due to leakage in oil-piping system took place on the English destroyer *Spiteful.* C. DeGrave Sells, in "Warship Engineering," makes the following remarks on this accident:

"Preparations were being made for raising steam and one of the sprayers was being lighted, but it seems that one of the union-joint nuts had been disconnected and not made good again, so that when the oil was turned on a jet of oil squirted out right across the stokehold and this took fire. The stokehold was immediately filled with heavy black smoke and a lurid, red flame, which cut off the escape of two of the stokers, and the poor fellows were burnt to death.

"The stokehold was flooded and the flames were eventually quenched without further damage being done.

"To prevent a similar occurrence, special orders were issued that after any overhaul or repairs the whole of the oil system between the pumps and sprayers is to be tested to the maximum working oil pressure before starting to light up, so that any leakage may be detected. Should it be necessary to remove a sprayer it is never to be left disconnected, and a screw plug is to be inserted in its place at the end of the pipe. Special

recommendations have also been given that should a leakage occur at any time, immediate action is to be taken to shut off the supply valves and to stop the oil pumps instantly, and the engineer officers of those vessels which are fitted for liquid-fuel burning are not only to impress upon their staff the importance of this matter, but are to see that they fully understand what steps to take to carry out the instructions."

Although with good design and workmanship and intelligent and careful operation the oil-burning system can be made thoroughly safe, it must be said that there is an element of danger that is not present when using coal, and the operation of a large oil-burning installation will require extreme care in securing tight joints for every part of the system containing the oil, and absolutely *careful* and *reliable* attendants to look after the system and to see that the necessary safety requirements are complied with. This requires a higher degree of skill and training than is necessary to burn coal without danger. Hence for oil-burning apparatus a higher grade of operating personnel is necessary. This is, however, but in line with the same need for higher classed engineering talent required with other great improvements that are being introduced into up-to-date naval engineering, such as the use of turbine machinery, improved condensing apparatus, superheated steam, etc.

AVAILABILITY OF OIL SUPPLY.

The question of the availability of a good supply of fuel oil at ports throughout the world is another matter that must be considered.

Coal can be obtained at practically every seaport in the world, but with oil this is far from being the case. While oil can be supplied in considerable quantities at the ports mentioned on pages 104 and 118, at many of these a large quantity would have to be ordered well in advance. Even on our own Atlantic coast there are very few ports were a large supply of oil, say, several thousand tons, could be obtained on short notice. Outside of Delaware Bay, Boston and New York the oil would probably

have to be supplied as ordered. The same way in Europe, outside of the very large commercial ports along the principal trade routes or adjacent to the oil-producing districts, oil cannot be secured in quantities except by ordering ahead and having it shipped there. As the use of oil in different navies and its general use in the merchant service is extended, this condition will improve. But for the successful use of oil fuel for our fleet, even in home waters on the Atlantic coast, it would be necessary for the Government to establish oil-fuel stations, since the commercial oil-fuel supply stations are too few and far between, and a regular supply a question of doubt and uncertainty.

A sudden increase in the use of fuel oil for steaming purposes might also result in a considerable advance in price, but as new oil fields are thrown open this danger will be lessened, and could be in a large measure avoided by the Government keeping extensive oil supplies at various fueling depots, the supply to be obtained when market conditions as to price were the most advantageous.

POSSIBILITIES OF OIL IN NAVAL VESSELS.

The difficulty of the supply of oil and the difficulty of securing safe stowage for full fuel supply on a man-of-war being such as it is, it is evident that it would not be a good military policy to adopt the exclusive use of oil for a vessel likely to be engaged in battle or likely to be engaged in extended operations away from a home base.

Therefore, the advantage of use of oil fuel on such men-of-war, exclusive of harbor-defense vessels, can, under present conditions, *only be realized by using it in combination with a coal-burning installation.*

The question now comes as to the character of such a combination. The system thus far employed in most naval vessels has been to provide a limited oil capacity, about 20 per cent. of the coal capacity, and to fit all boilers so that they may use either coal or oil, according to whichever may be at hand.

Another method would be to have one portion of the boilers

arranged for coal burning and another portion exclusively for oil burning. The first method has the advantage that full power may be secured with either coal or oil alone. On the other hand, it has the disadvantages that each boiler and boiler compartment must be fitted with a complete outfit of accessories for burning coal as well as for burning oil, including arrangements for disposing of ashes, etc. Also, one system is bound to interfere to some extent with the other, and the greatest efficiency of oil burning cannot be realized with a boiler fitted for burning both coal and oil. The burners cannot be placed to best advantage, and the most efficient furnace construction cannot be used. The boilers are restricted in their dimensions by the necessary requirements of the grate, so that many of the particular advantages of the oil apparatus are lost, and obviously such a combination will weigh and cost considerably more than either an all-coal or an all-oil burning apparatus.

Naval vessels have thus far only had what might be called the alternating oil-coal installation. By this the advantages gained are a slight gain in steaming radius and the ability to keep up full power with the oil, when coal is in distant bunkers, firemen fatigued or fires dirty. Full power is possible with either oil or coal, and this is the great point of advantage for this system.

The whole weight of the oil-burning apparatus is in this system an added weight, and many of the most apparent military advantages possible from the use of oil fuel are not realized. The added weight on a battleship is about thirty-five tons.

SEPARATE COMBINATION SYSTEM.

Another combination would be to have a portion of the boilers arranged exclusively for oil and another portion exclusively for coal.

This arrangement has the great objection that for full power there must be present both a supply of coal and a supply of oil. However, as coal is obtainable most anywhere, the oil supply

would be the troublesome question. In a vessel thus arranged it should be the policy to always maintain the reserve supply in oil; since oil weighs less for same power, this would be the most natural thing to do in any case.

When a part of the boilers are fitted exclusively for oil the oil installation could be more efficient, since furnaces, burners, etc., could be arranged to secure full advantage; likewise, fire-room space could be saved and the boiler made longer (thus securing greater lightness and economizing space) than where coal is to be used. A very considerable saving of weight would be made, since the oil-burning apparatus would only be in a portion of the boilers, and the weight of grates, ash hoists, ejectors, etc., for boilers fitted with oil would also be saved. This saving on a battleship over the alternative system would be about fifty tons in weight and about $45,000 in cost of apparatus.

In our recent battleships twelve large boilers in three boiler rooms are employed. The middle boilers might be arranged for oil burning. In the same space the boilers could be lengthened, using longer tubes, and the heating surface might also be further increased by making the boilers higher, so that, considering uniformity of steam, and no loss due to dirty fires and irregular firing (an increase of about 20 per cent.), these oil-burning boilers might be made to give a maximum evaporation equal to about two-thirds of what the other eight coal-burning boilers would give, or about 40 per cent. of the total power.

The bunker spaces abreast this middle group of boilers could be partially used for the installation of the oil-burning apparatus, pumps, heaters, etc., and the other portions could be arranged for coal to deliver to the coal-burning boilers. By doing this there is a larger supply of coal in close proximity to the boilers using it, and as the full coal supply is decreased, there is no need of having bunkers distant from the boiler rooms, from which it is difficult to take the coal.

The distribution of the fuel supply for a battleship would be about as follows: Total fuel capacity, 2,400 tons, divided: 1,800 tons coal, 600 tons oil. This oil is equivalent to 1,000

tons of coal, so that the total capacity would be equal to 2,800 tons of coal. Thus for the same steaming radius there is a saving of 400 tons weight by the use of oil fuel.

With the alternative combination it would be necessary to have a full force of firemen sufficient for all the boilers, but with the separate system the fireroom force could be reduced by the decrease in number allowed for the oil-burning boilers. This allowable decrease, about thirty men on a battleship, is a potent military factor, especially on a long cruise, where the complement may be depleted by sickness or casualties.

It will thus be seen that by the sacrifice of the ability to get full power by either coal or oil exclusively, very great advantages can be obtained, namely, about 15 per cent. reduction in fireroom personnel, two-thirds saving in cost of oil installation, one-third saving in installation of ash hoists, ejectors, firing tools and bunker apparatus.

A more efficient oil-burning apparatus, as well as a more efficient coal-burning apparatus, is obtained. By the reduction in weight either the steaming radius or the power may be increased on the same allowance for fuel.

In the case of scout cruisers the same general division as to oil-burning and coal-burning boilers could be made for the same reasons.

The fuel capacity of 1,400 tons could be divided into 1,000 tons coal, 400 tons oil, equal to a total of 1,700 tons coal capacity, a saving of 300 tons. The additional saving due to decrease—ash hoist, ash ejectors, grates, etc.—of about 25 tons could also be made.

In the case of torpedo-boat destroyers, the question of weight being of more importance, one-half of the boilers should be equipped for oil burning. The fuel capacity should be divided about as follows: 80 tons coal, 70 tons oil, giving an equivalent of 190 tons of coal, a saving of 40 tons. Also on the destroyer the reduced fireroom force required would be a most material advantage, since it allows a material reduction in berthing space, etc., for the accommodation of extra men that would be required for coal burning.

For torpedo boats operating from a base, oil-burning apparatus exclusively is suggested wherever oil can be obtained at a reasonable cost as compared with cost of coal.

The question of economy of operation is in this case not so very material, and as the oil fuel increases the steaming radius and requires fewer men for operation, it is unquestionably more advantageous for craft of this kind.

OIL SUPPLY.

If oil burning is to be largely used in the Navy, it is absolutely essential that a supply of oil fuel be guaranteed. If this is not done the oil-burning apparatus is likely to be useless.

To this end oil-fuel depots in connection with coaling plants should be established, and arrangements entered into to secure a supply of oil fuel at various commercial ports in a manner similar to what has been done by the system of coal contracts.

Oil-fueling vessels should be supplied and fleet colliers fitted to carry oil fuel as well as coal. As in any case, both coal and oil would be used by the fleet, it would seem to be the proper thing to equip all colliers building for the Navy with tanks for carrying oil fuel as well as coal. This could be done at very little extra expense, and would help to enable our Navy to realize some of the advantages of oil fuel.

Thus far in this country no steps have been taken to secure a regular supply of oil fuel for our vessels of war, although oil-fuel apparatus is being put into many of our new vessels.

The question of providing a supply of fuel oil for the service of naval vessels has had extensive attention in the British Navy. Several oil-tank vessels have been provided for carrying the fuel from the oil fields to the storage depots. Several obsolete vessels have been converted to be used for the stowage of oil fuel at the various dockyards. Depots for oil have been built or are under construction as follows: A large depot at Turnchapel, near Plymouth, having a storage capacity of over 30,000 tons; another depot of similar capacity at Portsmouth. On the Mersey, above Port Victoria, there is to be a station of 20,000 tons capacity. This will be provided with berthing

accommodations, so that naval vessels can come alongside and have the oil pumped in directly from the tanks on shore. Stations are also to be provided at South Shields, Granton, Invergordon, Harwich and Grimsby.

Oil can be obtained from large commercial storage depots at the following maratime ports: Thames Haven and Central Thames, London; at Manchester, Barrow and Bristol, while extensive supplies of oil are kept at Suez, Colombo, Calcutta, Bombay, Madras, Penany, Singapore, Batavia, Hong Kong, Bangkok, Sourabaya, Shanghai, Port Arthur, Manila, Nagasaki, Yokohama, and at Balicpoppan, Borneo, in the Black Sea, at Constantza, Roumania; in the United States chiefly at Texas and the California ports, while there are limited stores of oil at the principal ports of both North and South America.

The question of using oil fuel in naval vessels is not alone an engineering question. It is also a military question. The engineering features for enabling oil fuel to be satisfactorily used have now been practically solved. So now the manner of securing the advantages of oil fuel is a matter to be largely governed by the way in which a supply of fuel is provided for naval vessels. If a proper system of the supply of oil fuel is provided, then the important advantages of its use may in a large measure be realized. If means of supply are not provided it is almost futile to fit our vessels with any kind of oil-burning apparatus.

SCREW PROPELLER CRITICISM AND NOTES ON SCREW PROPELLER DESIGN BASED ON ACTUAL STANDARDIZATION TRIAL RESULTS OF U. S. VESSELS.

By Commander C. W. Dyson, U. S. N., Member.

In arriving at the results embodied in the following article the results of the trials of over sixty vessels varying in size from a 50-foot launch up to a 16,000-ton battleship and a 14,600-ton armored cruiser, and from the fineness of line of a torpedo boat to the fullness of hull of a monitor, have been employed. Also, in the prosecution of the investigation the E.H.P. curves obtained by towing models of the various hulls considered in the model tank at Washington have been of the greatest assistance, in fact, were invaluable, in arriving at the respective values of the propulsive coefficients. In using these curves those obtained by towing the naked hull have been used, as it is considered doubtful whether the law of comparison holds for hulls towed with the appendages.

In many cases, particularly in those where vessels were not required to be standardized before their acceptance trials, the data given is very misleading. In the majority of these cases the propulsive coefficient curve will be found to be falling very rapidly until just before the maximum speed reported has been reached, when the curve begins to rise at a rapid rate. This would seem to indicate a certain amount of optimism, so far as speed was concerned, on the part of the trial observers, and casts a doubt on the reported results of these trials.

In laying down the results of the trials the indicated thrusts for reciprocating engine propellers, or meter thrusts in the case of turbine propellers, per square inch of projected area have been used in preference to those per square inch of helicoidal area, as the variations in the latter were found to be excessive and impossible to bring to agreement.

GENERAL DESCRIPTION OF CHART I.

The attempt has been made to lay down a line of design, shown by curve and lines C, Chart 1, which will give a perfectly practical propeller under ordinary conditions, so far as weight and surface are concerned, and which will render with certainty an efficiency varying from a propulsive efficiency of 50 per cent. at abscissae 1,200 to an efficiency of 57 per cent. at abscissae 10, the percentage efficiency at intermediate points being a simple matter of proportion. However, these lines C cannot be used for torpedo boats and destroyers on account of the limitations in diameter. In these cases we must use the approximate thrusts given by middle lines B for the projected areas, going as much below this line as possible, while the disc thrusts will more closely follow disc-thrust line F of Chart 2, and the slips the upper slip line A. As B approaches more closely to C, or, in other words, as the conditions become such as to allow us to use thrusts approximating more closely to those of thrust line C, the slips depart more and more from those of slip curve B and approach those of C. As we pass below thrust line C and approach line D and disc-thrust line D the slips will still further decrease until slip curve D is reached. As thrust values used approach thrust line B the vibrations of the propellers will slowly increase, and at B are rather marked. As the values used exceed B and approach more closely to A the vibrations are very apt to become excessive, although this may be due to other reasons, as explained later. As lack of vibration, on account of the necessity of being able to keep gun sights bearing on the target while running at full speed, is of the first importance in a war vessel, thrusts should be held down to the lower value given by lines C as much as possible, even lower than given by these lines at the higher values of the abscissae, in order to obtain smooth running at high speeds. Slip curves A, B, C and D extended as A′, B′, C′ and D′, show slips to be expected where thrusts are held down by means of large surface instead of by high pitch. Such propellers are smooth running, but their maneuvering powers are apt to be poor.

The curve and lines D are not the extreme maximums which

our propellers have shown, but are a conservative line of maximums, being 60 per cent. where the projected thrust line crosses the 7½-pound thrust line and 57 per cent. where it crosses the 10-pound line, intermediate values being obtained by proportion.

In figuring the thrusts the following formulae are employed: Indicated thrust per square inch of projected surface = (Indicated horsepower × 33,000) ÷ (Pitch × Revolutions × Projected Area in Square Inches), and Shaft or Meter Thrust = (Shaft horsepower × 33,000)÷(Pitch × Revolutions × Projected Area in Square Inches). For the disc thrusts the same formulae are used, replacing square inches of Projected Area by Square Inches of Disc Area (including hub).

In designing propellers for ships of war on which the usual cruising speed is far below the designed maximum speed, and where we are certain of having an ample reserve of power to obtain the designed speed, it may be advisable to design the propeller for economy at the lower speed. If this is the case, very good results will be obtained by following the lines E, Chart 1, of thrusts and slip, the approximate values of the propulsive coefficients being proportional to the positions of the points on the line E relative to lines B and C and to B and A.

Formula for Abscissae Values.—In laying down the curves of performance, in order to arrive at a proper means of comparison, it was first necessary to derive such values of abscissae that apparent discrepancies should be smoothed away as much as possible. It was only after a vast amount of labor and the construction and discarding of many charts with many different values of the abscissae that a satisfactory value was finally obtained. The abscissae finally used are derived from the formula: $X =$ (Displacement $^{2/3}$ × Speed in knots per hour ^{3}) ÷ K, where K = Block Coefficient multiplied by 10,000, this factor 10,000 being introduced in order to increase the size of the units.

This formula resulted in the production of as satisfactory results as appear possible to be obtained when it is taken into consideration that the results obtained for each vessel were not

only influenced by the size and form of the vessel itself, but also by the condition of bottom, the state and direction of wind and sea, and the skill of the helmsmen, also the amount of initial friction in the engines due to the varying practices of the personnel engaged both in the erection and in the care of the machinery, in the adjustment of the running parts of the engines; and also to variations in displacement and trim.

Upon examination of Chart 1, and the performance curves shown on Plates 1 to 64, it appears that while considerable latitude may be exercised in the amount of apparent slip and indicated thrust per square inch of projected area without seriously affecting the propulsive coefficients, the same latitude does not exist in the case of the indicated thrusts per square inch of disc area; in other words, the most important detail in the design is the diameter.

We also see that as the indicated thrusts per square inch of disc area are increased above those indicated by line C, in order to prevent too rapid a decrease in the value of the propulsive coefficient, a heavy increase in the projected areas must be made in order to obtain a low value of indicated thrust per square inch of projected area.

From an examination of the performances of the *Chester, Salem* and *Creole* we will find this point further illustrated, as in all of these cases except with one set of propellers on the *Creole,* the propulsive efficiency increases as the diameter of the propeller is increased and the thrust per square inch of disc brought nearer to those shown on Chart 1.

In the case of the turbine ships, Chart 2, with propellers of low pitch and high speed of rotation, a maximum value of meter thrust to hold 50 per cent. propulsive efficiency appears to be reached at about 16 pounds per square inch of projected area, and in the case of propellers having comparatively high pitch and low speed of rotation an indicated thrust of about 13½ pounds per square inch, as upon reaching these values the curves of propulsive coefficients in both cases are falling rapidly. In the latter case, however, it is believed that the propulsive coefficient would hold up with still higher thrusts per

square inch of projected surface, provided the indicated thrusts per square inch of disc area were held down to a value of between 3½ and 4 pounds per square inch. This, of course, would result in the use of larger diameters for our large fast vessels than we have been using, lack of diameter in these screws appearing to be the main reason for the falling off in efficiency which they show at the high speeds realized.

CHART 2.—TURBINE PROPELLERS.

Our data on this subject is very meager, and some of it is not very reliable, therefore nothing particularly definite can be done with them. The curves of performances shown on Plates 65 to 74 and Chart 2 will give a general indication of the direction in which to work for an improvement in efficiency. On Chart 2, lines B, the *Chester's* propeller performance, in passing from abscissa 360 to abscissa 900, maintains an almost constant propulsive coefficient of 51 per cent., with a slip rising gradually from 19 per cent. to 20½ per cent., with meter thrusts per square inch of projected and disc areas of 7.2 and 4.7 pounds and 16.2 and 10 pounds, while the *Salem's* propellers between the same limits show a coefficient of about 60 per cent., with corresponding slips and thrusts of 17 to 17½ per cent., 6.2 and 3.3 and 12.9 and 7.4 pounds. At the upper limit both propellers have reached about the same tip speed of slightly over 10,000 feet per minute, and the propulsive coefficient curve in both cases begins to fall rapidly, reaching a value of 57.2 per cent. at 10,890 feet tip speed for the *Salem,* and the *Chester* a coefficient of 48.7 per cent at the same speed. Basing our conclusion on these two examples, we may assume that we have reached a critical tip speed at 10,000 feet per minute, beyond which we cannot hope to maintain a high propulsive efficiency. High authority on turbine propellers fixes about 14,000 feet as the upper limit of tip speed, at which we may expect to obtain a fair efficiency of propulsion.

As the meter thrusts of the *Chester's* propellers draw down towards those of the *Salem,* between abscissa 300 and the origin, the propulsive coefficient gradually increases until a

value of 59 per cent. is reached. As those of the *Salem* fall between the same limits the efficiency also increases until a maximum of 64.5 per cent. is reached. Lines A are based on points in performances of *Creole* No. 4 propeller and in the *Chester's* propeller performances, and is for a propulsive coefficient of 46.5 per cent., with meter thrusts per square inch of projected and disc areas, tip speeds and slips at abscissa 373 of 11.25 pounds, 6.6 pounds, 8,450 feet per minute and 27.4 per cent. slip to 22.5 pounds, 13.75 pounds, 11,560 feet per minute and 28.4 per cent. slip at abscissa 1,082.

Lines B are those along which the propellers of the *Chester* maintained a propulsive coefficient of about 51 per cent. until a tip speed of 10,000 feet per minute was reached. If projected surface and disc could have been increased sufficiently to have held the meter thrusts and slip to these lines it is probable that this efficiency would have been maintained at higher powers.

Lines C are the corresponding lines for the *Salem's* propellers, along which an approximate coefficient of 60 per cent. was maintained, lines D 61.5 per cent. and lines E 64.5 per cent. The same remark applies to these lines as to lines B.

Lines F are drawn through a point of 48.5 per cent. propulsive coefficiency with propeller No. 6 of the *Creole*, located at abscissa 261, with meter thrusts, slip and tip speed of 7.2 and 4.8 pounds, 18 per cent. and 7,964 feet, and through point on *Salem's* 64.5 per cent. line extended to abscissa 1,300, where the corresponding thrusts and slip would be 16.2 and 8.2 pounds and 17.2 per cent. slip. It would have been preferable to have drawn these lines F to *Salem's* 60 per cent. lines at abscissa 900, for which the values are 12.9 and 7.2 pounds, 17½ per cent. and 10,250 feet.

From a study of the curves of performance of all the turbine propellers we again find thrusts per square inch of disc area playing the most important part, and that in each case the closer they approach to those of the *Salem's* second propeller the more efficient becomes the combined propelling agent.

CONTOUR OF BLADES.

The generally accepted opinion regarding blade contour is that it has but little, if any, effect upon the efficiency of performance of the blade. This may possibly be so, but it does not seem to be a very reasonable conclusion, as it would appear that with every blade there would be a radius at which the resultant fore-and-aft thrust would be a maximum per unit of area, and that the blade should be of such form that its projected circular width should be a maximum at this radius, the form of the blade between this radius and the hub to be such as will provide ample strength and stiffness with the minimum resistance. If in our design we must carry greater thrusts per square inch of disc area than are called for by lower line C, then the blade should be made broader towards the tip.

A proposed standard series of forms of projected areas for various ratios of projected area to disc area, and a chart of diagonals showing the approximate ratios of helicoidal area to disc area for corresponding projected area ratios and for pitch ratios varying from .8 to 2.0, are also given on Chart 1. These projected areas are half projections of blades, and the ratios given are for total projected areas of the three blades of 3-bladed propellers to disc area, including the hub.

On the diagram of projected blade shapes, Chart 1, are shown the circular arc projections on the disc of the greatest developed elliptical widths of the blades for pitch ratios varying from .8 to 2, which will give these projected forms.

These blade forms are based on the performances of the successful propellers of the *Salem*. As the greatest width of the projected blade moves in from the point shown on the diagram, the slip appears to increase slowly and the speed of rotation of the propeller becomes higher. When the diameters are reduced below those called for by curve C, Chart 1, provided the shape of the blade would remain as shown on the diagram, there would also be a gradual increase in slip accompanied by a decrease in propulsive efficiency. This latter effect can, however, be partially guarded against by laying down the blade as designed for the proper diameter to be used if it were possible,

and then to widen from the greatest width as given by this layout towards the actual tip as fixed by the diameter that circumstances require us to use.

In Sheets 1 to 26, inclusive, one-half of the projected areas of each of the blades studied are given, together with the blade sections tangent to the hubs. In order to compare the forms more easily, all propellers have been brought to a common diameter of 18 feet, and the sections are drawn to the same scale, all projected areas being arranged symmetrically around the center line of the blade normal to the axis of the hub.

Upon these projected areas are shown in dotted lines the standard form of blade, Chart 1, having approximately the same projected area.

A comparison of these forms will show that the majority of the most successful propellers have projected area forms approximating very closely to the proposed standard forms of projection, while, of those not having these forms, the most successful, but lacking in diameter, are broader at the tips of blades, while those having sufficient diameter but narrow at the tip show higher rates of slip than the value of their indicated thrusts, as shown on Chart 1, would call for. This latter case is shown very well in the performance of the *Connecticut,* and the former in that of the *Wyoming's* second propeller as finally adopted for service, *Wyoming* No. 3.

Width and Thickness of Blade and Shape of Blade Section Tangent to Hub.—These three elements, judging from results obtained in practice, appear within certain limits to have considerable influence upon propulsive efficiency. We find one notable case in the naval service, where the propellers of one vessel were far inferior to those of her sister ships, the only difference of any moment in the propellers being in the shape of blade section at the hub, the blade being abnormally thick, having an extremely abrupt entrance and being cut away heavily on the driving face both at the entering and at the leaving edge.

In several other cases the blade has been very narrow tangent to the hub and the ratio of thickness to width has been large. The amount of surface carried by each blade has also

been large. In all of these cases when the thrust became high the form of the performance curves show distinctly that some radical change has occurred in the pitch of the blade; in other words, the blade has twisted at the root under high strains.

For best results the blades should be made comparatively wide at the hub and as thin as practice shows us we may safely go. In addition, a slight ease of entrance and consequent slight gain in propulsive efficiency, due to decreased eddying at root, may be produced by cutting away the driving face of the blade at the entering edge for a slight distance from the hub outward, as shown in Figures 41 and 49. The driving face at the leaving edge should be left at the designed pitch.

From the results obtained in practice it is certain that with manganese-bronze of 60,000 pounds tensile strength, and using a fiber stress of 10,000 pounds per square inch, a blade of ample strength may be obtained by making the thickness equal to from .15 to .18 of the tangent width of the blade at the hub, this width being derived by the following adaptation of the formula for thickness given by Naval Constructor D. W. Taylor, U. S. N., in his admirable work on "Resistance of Ships and Screw Propulsion":

T = thickness of blade at hub tangent to hub, fillets neglected = .15 W.

W = width of blade tangent to hub.

A = (33,000 × I.H.P.) ÷ 2π × revolutions × number of blades = 5,252 I.H.P. ÷ revolutions × number of blades = maximum indicated torque per blade in foot-pounds.

B = .31 × diameter of the screw in feet = mean arm.

$C = A \div B$ = resultant athwartship force on one blade in foot-pounds.

D = 12 × B — radius of hub in inches = arm of athwartship force measured to root of blade.

$E = C \times D$ = athwartship moment at root of blade in inch-pounds.

F = 33,000 × I.H.P. ÷ pitch in feet × number of revolutions × number of blades = indicated thrust per blade in pounds.

$G = .345 \times$ diameter of screw in inches = mean arm of thrust in inches.

$H = G -$ radius of hub in inches = arm of thrust measured to root of blade in inches.

$J = F \times H =$ fore-and-aft moment at root of blade in inch-pounds.

$K =$ circumference of hub in feet $\div$ pitch in feet = tangent of angle between face of blade and center line of hub or fore-and-aft line at surface of hub.

$L =$ sine of arc whose tangent is K.

$M =$ cosine of arc whose tangent is K.

$N = L \times J =$ component of fore-and-aft moment normal to face of blade at root.

$O = M \times E =$ same for athwartship moment.

$P = N + O =$ total moment at root of blade in inch-pounds.

Fiber stress $= 10{,}000 = P \times 13.125 \div W T^2 = P \times 13.125 \div .0225\ W^3$.

$$W^3 = \frac{P \times 13.125}{10{,}000 \times .0225} = \frac{P \times 13.125}{225}.$$

$$W = \sqrt[3]{P \times 13.125 \div 225}.$$

$$T = .15\ W.$$

This width, from practical results obtained, appears to be as great as is required to prevent unnecessary and wasteful eddying at the root.

REMARKS ON TABLE I.

Virginia—Vibration at high speed considerable.

Georgia—Vibration at high speed light.

Rhode Island—Vibration at high speed light.

Connecticut—Vibration at high speed almost nothing.

Minnesota—Vibration at high speed moderate.

Kansas—Vibration at high speed considerable, probably increased by shape of blade section.

Vermont—Curves of performance indicate a change of pitch under heavy loads.

TABLE I.

DIAMETER OF HUBS, WIDTHS OF BLADES TANGENT TO HUBS, RATIOS OF THICKNESS TO WIDTH OF BLADES TANGENT TO HUBS, AND MAXIMUM FIBER STRESSES ON BLADES.

Vessel.	Diameter of hub.	Width tangent to hub.	Ratio of thickness to width.	Thickness at 6 inches from tip.	Maximum horse-power on one propeller.	Diameter of propeller.	Pitch of propeller.	Revolutions of propeller.	Maximum fiber stress at root of blade.
	ft. *ins.*	*ins.*		*ins.*		*ft.* *ins.*	*ft.* *ins.*		
Virginia	4 06	44	.195	$1\frac{3}{8}$	11,086	17 3	18 3	129.25	11,380
Georgia	4 08	44	.199	$1\frac{7}{16}$	10,550	18 0	19 2	119.8	8,220
Rhode Island	4 08	48	.203	$1\frac{3}{8}$	10,800	17 9	18 8	125.4	6,480
Connecticut	4 03	50	.170	$1\frac{1}{8}$	9,667	17 9	17 $7\frac{1}{2}$	128.00	7,798
Minnesota	4 $04\frac{1}{2}$	38	.214	$1\frac{1}{4}$	9,948	17 3	18 5	122.93	10,940
Kansas	4 03	$43\frac{1}{2}$	.185	$1\frac{1}{4}$	9,651	17 4	17 6	121.32	10,464
Vermont	4 06	35	.239	$1\frac{1}{4}$	8,812	17 9	18 0	117.12	11,030
Maryland	4 06	$42\frac{1}{2}$	.204	$1\frac{1}{4}$	13,785	17 6	22 6	127.84	9,855
Pennsylvania	4 06	$40\frac{1}{2}$	.222	1	12,300	18 0	22 0	124.6	9,259
California	5 00	44	.169	1	13,750	18 0	21 6	122.85	13,675
Tennessee	4 06	$40\frac{1}{2}$	.222	1	13,000	18 0	22 0	126.00	9,677
Washington	4 08	$45\frac{1}{2}$	.188	$1\frac{1}{8}$	12,725	18 0	21 9	121.2	9,719
Montana, 1st propeller	4 06	$42\frac{1}{2}$	.202	$1\frac{1}{4}$	13,745	18 0	21 9	122.59	11,094
Charleston, 1st propeller	4 06	45	.176	$1\frac{1}{4}$	13,400	16 3	20 6	146.00	9,324
St. Louis	4 $07\frac{1}{2}$	$38\frac{1}{2}$	.297	$1\frac{1}{2}$	13,225	18 0	19 $5\frac{1}{2}$	149.5	5,980
Birmingham	3 10	29	.217	$1\frac{1}{8}$	8,050	12 6	15 3	193.6	10,021
* *Salem*, No. 2 propeller	1 $09\frac{3}{16}$	31	.152	$0\frac{3}{4}$	9,600	9 6	8 8	378.3	15,500
* *Chester*	1 $04\frac{1}{2}$	29	.121	$1\frac{1}{16}$	6,250	6 0	6 0	613.00	10,650

* Meter horsepower.

Maryland—Vibration at high speed moderate.

Pennsylvania—Vibration at high speed moderate.

California—Vibration at high speed heavy.

Tennessee—Vibration at high speed moderate.

Washington—Vibration at high speed moderate.

Montana—Vibration at high speed considerable.

Charleston—Vibration at high speed heavy, probably due to high pitch and lack of surface.

St. Louis—Vibration at high speed considerable, probably due to inherent weakness in form of blade while blade is more than amply strong at the root.

Birmingham—Vibration at high speed very moderate.

For turbine propellers, on account of the steadiness of torque, a very much higher fiber stress appears permissible, as shown in the case of the *Salem,* where at the maximum speed realized the propeller vibration was very light.

Angle of Inclination of the Blades Astern.—It is believed that where the blades revolve well clear of struts or stern post, so that no eddying can occur from the blades passing these obstructions, nothing whatever is gained by throwing the tips of the blades to the rear; neither is any gain obtained by scimitar or other peculiar-shaped blades. Actual results obtained in practice do not show any gain to accrue. Where the blades are turning perfectly clear of obstructions it would seem that an actual loss of efficiency would result on account of the greater amount of developed surface necessary in the first case to obtain the required projected surface, and the consequent increase in skin-friction loss of the blade; in the case of blades of odd form, loss probably occurs through change of form under heavy thrusts.

This last case will be met with in the blades of the *Denver* and the *St. Louis,* which, in addition to being inclined to the rear, were also trailed to the side. This trailing seems to destroy the rigidity of the blades and permits them to change their pitches under heavy loads. This change appears to the writer to be toward a lower pitch, as in figuring out results at the higher powers, using the nominal pitch of

the blades, an undue rapid increase in slip is found, while the rate of increase in indicated thrusts falls off very rapidly.

PERFORMANCES OF VESSELS.

Launches Santa Barbara and No. 691.—A common mistake made in the design of propellers for launches is to design for too high a thrust per square inch of developed and projected areas. This is a fatal mistake, as, due to the limited diameter of such propellers, the speed of revolution obtained becomes very high, and excessive vibration occurs. This fault was very thoroughly illustrated in the case of the launches named above.

In the case of the *Santa Barbara,* with the first propellers fitted, the diameter was 2 feet 11 inches, with pitch of about 3 feet. This propeller allowed the engine to run away, and at 400 revolutions gave a speed of about 8 knots. A new propeller, having a diameter of 3 feet 5 inches, and a pitch of 3 feet 10 inches, was fitted. This propeller was designed for 370 revolutions, 12 knots, and about 6 pounds indicated thrust per square inch of projected area. The results obtained were very satisfactory, being 11.98 knots, between 370 and 380 revolutions, and a disappearance of vibration.

The same experience was had with launch *691,* where the speed increased from about 10½ knots to 11.38 knots, and nearly all vibration, which had been excessive with the original propeller, disappeared.

The forms of the projected areas of these blades are shown in figures 62, 63. The blades, on account of the limited diameters, are broadened at the tip more than proposed standard form, and are narrower at the hub, as a length of hub equal to that of the old hub had to be used. This narrowness at the hub made it necessary to make the blades thick at the root and probably considerable loss due to this resulted.

Ferry Launch Castro.—The results obtained with this propeller were satisfactory, the thrusts per square inch of projected area and per square inch of disc area plot about on lines C, Chart 1. The slip is higher than it should have been, due probably to blade form, as shown in Fig. 67.

Torpedo Boats—Craven, Barney, Thornton.—See Plates Nos. 58, 57, 59, and blade form figures Nos. 58, 59 and 60.

All three of these vessels gave excellent performances, although the values of them are doubtful as the trials were not conducted with the care of later trials, and a small error in speed observation will make a very considerable difference in the propulsive coefficients. The vibration of the *Thornton* was heavy. While the indicated thrust per square inch of projected area of the *Thornton* was high, the thrust for her and for the other two vessels per square inch of disc area was low as compared with other torpedo boats and small destroyers. The thrust per square inch of projected area for the *Craven* and *Barney* fall very close to thrust line E. The nominal slips of these two vessels was very low, while that of the *Thornton* was moderately high. In all three cases there is shown an unaccountable rise in the curves of propulsive coefficients at the top speeds with which they are credited. The speeds were probably lower than the recorded speeds and the propulsive coefficients therefore lower. The values of the propulsive coefficients probably fall gradually from the lowest speed observed to the highest.

The blade forms all approximate closely to the proposed standard except at the hub, where, to avoid excessive thickness, the blades were broadened. The blades of the *Thornton* are slightly broadened at the tip over the standard form, which would tend to increase their efficiency as her propellers lack in disc area.

The attention of the reader is called to the performance curves of these three vessels in which the effect of the change of water line at high speed is fully exemplified, where, according to Barnaby, "she is seen to rise in the water, the bow is eventually lifted out of it, and the vessel settles down to speeds gained with comparative ease under the new conditions."

Destroyers Paul Jones, Perry, Preble, Bainbridge, Lawrence and Truxtun.—See Plates 54, 55, 56, 53, 52, 51, 50, and Figures 52, 53, 54, 55, 56, 57.

Of these vessels, the propellers stood in their order of per-

formance as follows: *Paul Jones, Truxtun* and *Preble, Bainbridge, Lawrence, Perry.* The indicated thrust of the *Paul Jones* per square inch of projected area was the lowest of all these vessels, and per square inch of disc area was a little more than that of the *Preble* and *Bainbridge,* while the vibration of the vessel at top speed was practically *nil.* The efficiencies of the propellers of the *Preble* was maintained by lowering the indicated thrust per square inch of disc, as was the case with the *Truxtun.* Vibration, however, in these two vessels was quite heavy.

The performance of the *Preble* is, however, doubtful, as is shown by the unaccountable decrease in increment of thrusts above 7,800 feet tip speed per minute.

The *Lawrence* lacked in surface and the pitch was too low, while the *Perry* lacked in surface.

The entire number lacked in disc area, a fault which we will find repeated in turbine propellers.

The *Bainbridge* would probably have done better with a decided increase in projected surface and a decrease in pitch, resulting in a decrease in slip and indicated thrusts.

The blade shapes of the *Paul Jones* and *Bainbridge* approximate closely to the proposed standard forms, while those of the *Perry, Preble* and *Truxtun* are broader towards the hub and narrower at the tips, differences tending to an increase in slip and a decrease in efficiency, while those of the *Lawrence* are narrower near the hub and broader towards the tip than the standard, thus decreasing the slip below the slip line B. The *Paul Jones* would probably have been improved by making her blades wider and thinner at the root, as could easily have been done.

Protected Cruisers—Cleveland, Chattanooga, Galveston, Denver and *Tacoma.*—See Plates 39, 40, 41, 42, 43, and Figures 9, 34, 35, 36, 37.

The relative standing of the propellers of these vessels was in the order in which they are named.

The blade forms of the first two named are approximately of the standard form, the *Chattanooga's* being slightly fuller at

the tip. The *Galveston* blades are still fuller at the tip, while the *Denver's* are of abnormal form, very narrow at the hub and very full towards the tip.

It is reported of this propeller that the vibrations at high speed were excessive. This form of blade in a less exaggerated form is seen in the cases of the *Vermont*, Fig. 13; the *New Jersey* and *Rhode Island*, Fig. 27, and the *St. Louis*, Fig. 42. In the cases of the *Vermont* and *St. Louis* the nature of the performance curves leads us to believe that these blades sprung to a lower pitch at high powers. In the case of the *Denver* it is believed that this same effect was produced, and that in her case, as in many others where the thrusts are quite well below the cavitating point, the excessive vibration is due to a fluttering of the blades, due to the fluctuation in value of the turning moment during a revolution, this fluttering being much more readily produced on a broad-tipped narrow-necked blade than on one more symmetrically proportioned, and still more readily produced where, in addition to narrowness at the root, the blades trail aft and to one side, as in the cases of the *Denver* and *St. Louis*.

Monitors—Wyoming, (Cheyenne), Florida, (Tallahassee), Arkansas, Ozark, Nevada, Tonapah.—See Plates 44-49, and Figures 4, 30, 64, 65, 66.

Two sets of propellers were tried on the *Wyoming*, the second set being tried at two different pitches. The first propellers tried, Fig. 30, gave good results at low speeds, but at high speeds the results were poor, the slip high and the vibrations excessive. This propeller was replaced by the one shown in Fig. 4, which had 50 per cent. more area, one foot more in diameter and one foot less pitch. The results obtained were poor and the vessel handled very badly. The propellers were then set at the same pitch as the original ones. The results obtained by this change were excellent. The slip decreased, the indicated thrusts fell from 7.0 pounds and 3.0 pounds per square inch at 12 knots to 5.85 pounds and 2.7 pounds at 12.5 knots, while the horsepower changed from 2,800 at 12.38 knots to 2,600 at 12.55 knots. In both cases the pro-

pellers were very slightly lacking in disc area, and the forms of the projection show a very considerable broadening at the tips over the standard forms. The second set of propellers at both pitches were tried at cruising draught and do not show as well as they would at normal draught.

The best performance credited to any one of these vessels was that of the *Nevada,* closely followed by that of the *Arkansas.* Both of these performances, especially that of the *Nevada,* as regards speed, are doubtful, but the results, even allowing the doubt, were very good. The *Florida's* showing was also good, but not equal to those of the two just mentioned.

Attention is called to the low disc thrusts of these three vessels and of the *Wyoming* No. 3 blades, as compared with *Wyoming* No. 1. Both *Wyoming* No. 3 and *Florida* appear to have too high pitch.

The blade forms of the best two performers, the *Nevada* and *Arkansas,* approximate very closely to the proposed standard form, while the blades of the *Florida* are slightly broader at the tip. Nothing appears to have been gained by the very broad and thin blade sections at the roots of the blades of the *Wyoming's* and *Florida's* propellers.

Battleships Massachusetts and Oregon.—See Plate 1, see Figures 18 and 23, see Plate 2, see Figures 18, 22.

The results of the trials of these two vessels and the cruising results demonstrated fully the superiority of the propellers of the *Oregon* over those of the *Massachusetts.* The slip of the *Massachusetts* is high, the indicated thrust per square inch of projected area falls between thrust lines A and B, while that for disc area falls upon disc thrust line B. These thrusts, together with the high slip, show that our results should approximate closely to and possibly a little lower than 50 per cent. propulsive coefficient. The propulsive coefficient curve gives 52.8 per cent., and is rapidly rising, due probably to the optimism of the speed observers and the kindness of the Trial Board.

The thrusts of the *Oregon's* propeller are kept well down between lines B and C, as is also the slip. The speed credited

to her, and therefore the propulsive coefficient, are probably higher than actually made, for the same reasons as in the case of the *Massachusetts.*

The blade form of the *Oregon* is much nearer to the proposed standard form than that of the *Massachusetts,* which departs radically from it. This extreme departure in the case of the latter, a heavy broadening towards the root and narrowing at the tip, being without doubt one of the causes of the high slip of these propellers. Both blades were of sufficiently low ratio of T to W at hub to obviate loss due to excessive resistance, the *Oregon* being even lower than is considered needful.

Battleships Kearsarge, Alabama, Mississippi, Wisconsin.—See Plates 4, 7, 22, and Figures 17, 19, 20, 21.

The best performer among these vessels was the *Kearsarge,* while next to her was the *Alabama.* With both these vessels we find the indicated thrust per square inch of projected plotting slightly above, that per square inch of disc on and the slips on the C lines and curve. The thrusts of the *Mississippi* and *Wisconsin* are between the B and C lines, while the slips have increased to the B curve and above.

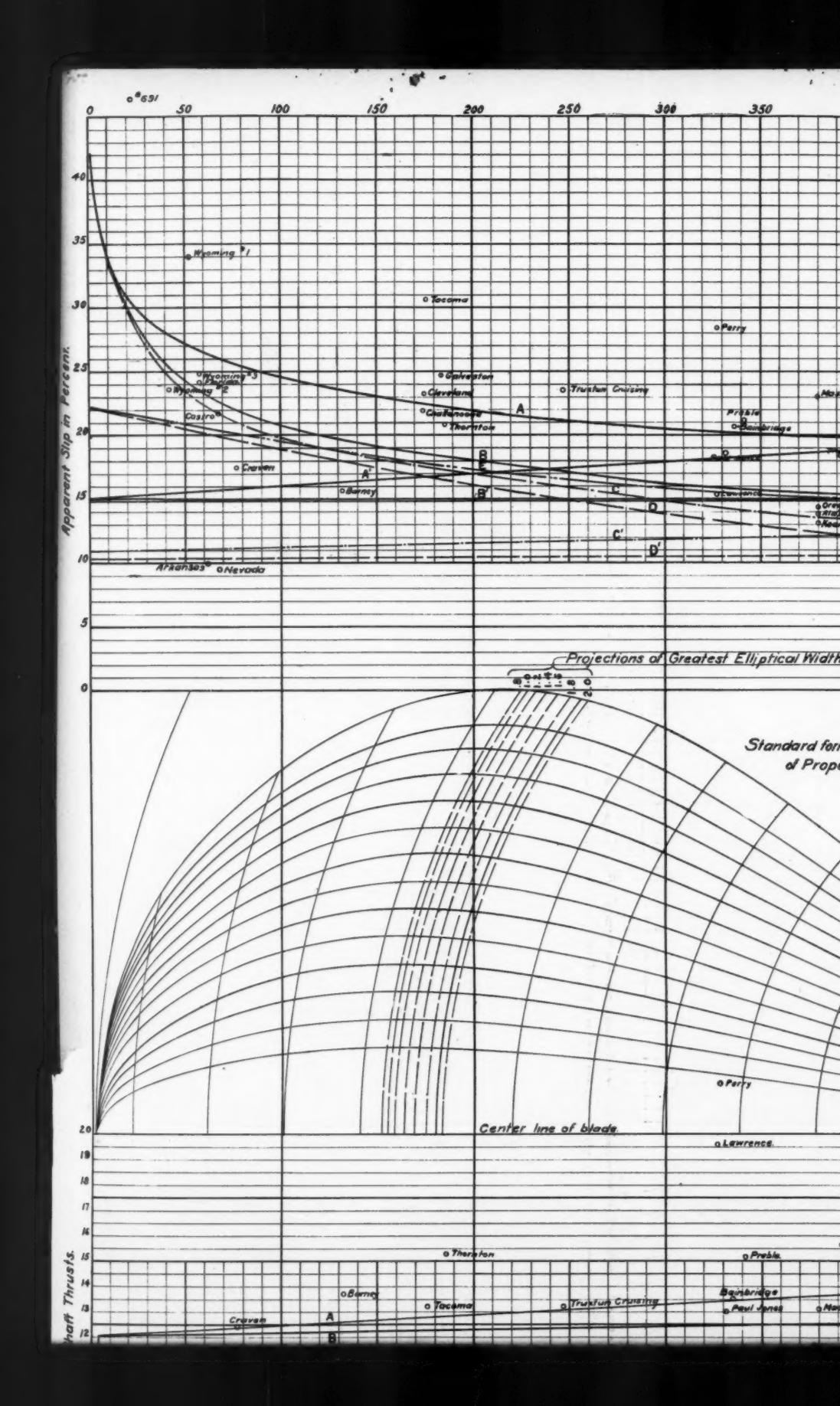
The blade form of the *Kearsarge* is almost identical with the standard form, while those of the *Alabama, Mississippi* and *Wisconsin* are narrower at the tip than the standard forms. The blades of the *Mississippi* are quite thick at the roots in proportion to their width.

The *Mississippi's* blades have been replaced by the blades shown in Fig. 61, the new blades having greater area, less pitch and less diameter than the old ones. Unofficial reports state that the new propellers have driven the vessel at 16.5 knots with 1,000 H.P. less than the old ones, but no official report of performance nor none of the data have as yet been received.

The form of these blades approximates closely to the proposed standard form, being, as in the case of the *Kearsarge,* slightly broader at the tips.

Battleship Iowa.—See Figure 33.

The results obtained with these propellers were very good.


Apparent Slip in Percent.
Shaft Thrust.
Projections of Greatest Elliptical Width
Standard form of Propeller
Center line of blade
Wyoming #1
Tacoma
Perry
Galveston
Cleveland
Chattanooga
Thornton
Trunkun Cruising
Preble
Bainbridge
Castro
Craven
Barney
Arkansas
Nevada
Lawrence
Paul Jones
A
B
C
D
A'
B'
C'
D'

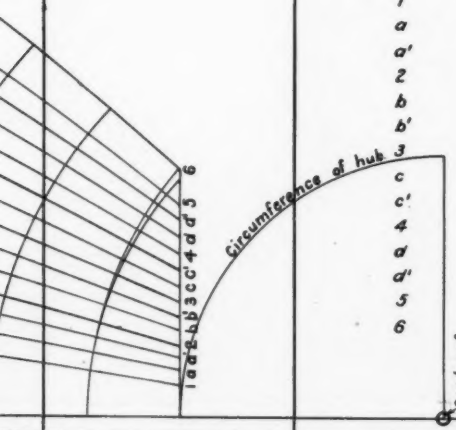
400 450 500 550 600 650 700 750 800

New York
Charleston
A
Massachusetts
Iowa
Maine
Wisconsin
Mississippi
Ohio
Louisiana
Virginia
Rhode Island
New Jersey
Nebraska
Georgia
New Hampshire
Connecticut
Minnesota
Vermont
Oregon
Alabama
Kearsarge
Missouri
Kansas
E
B
C
D

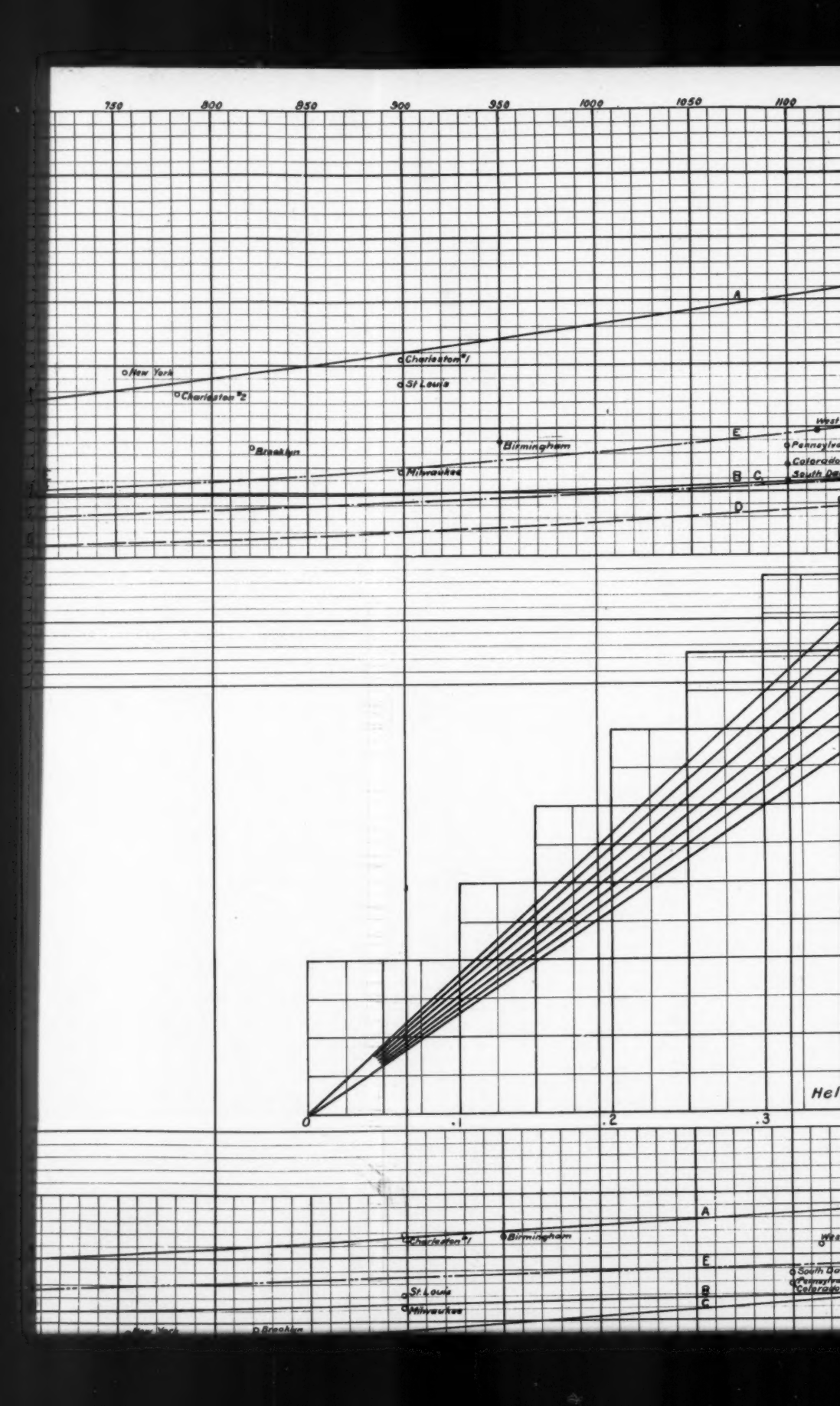
dths.

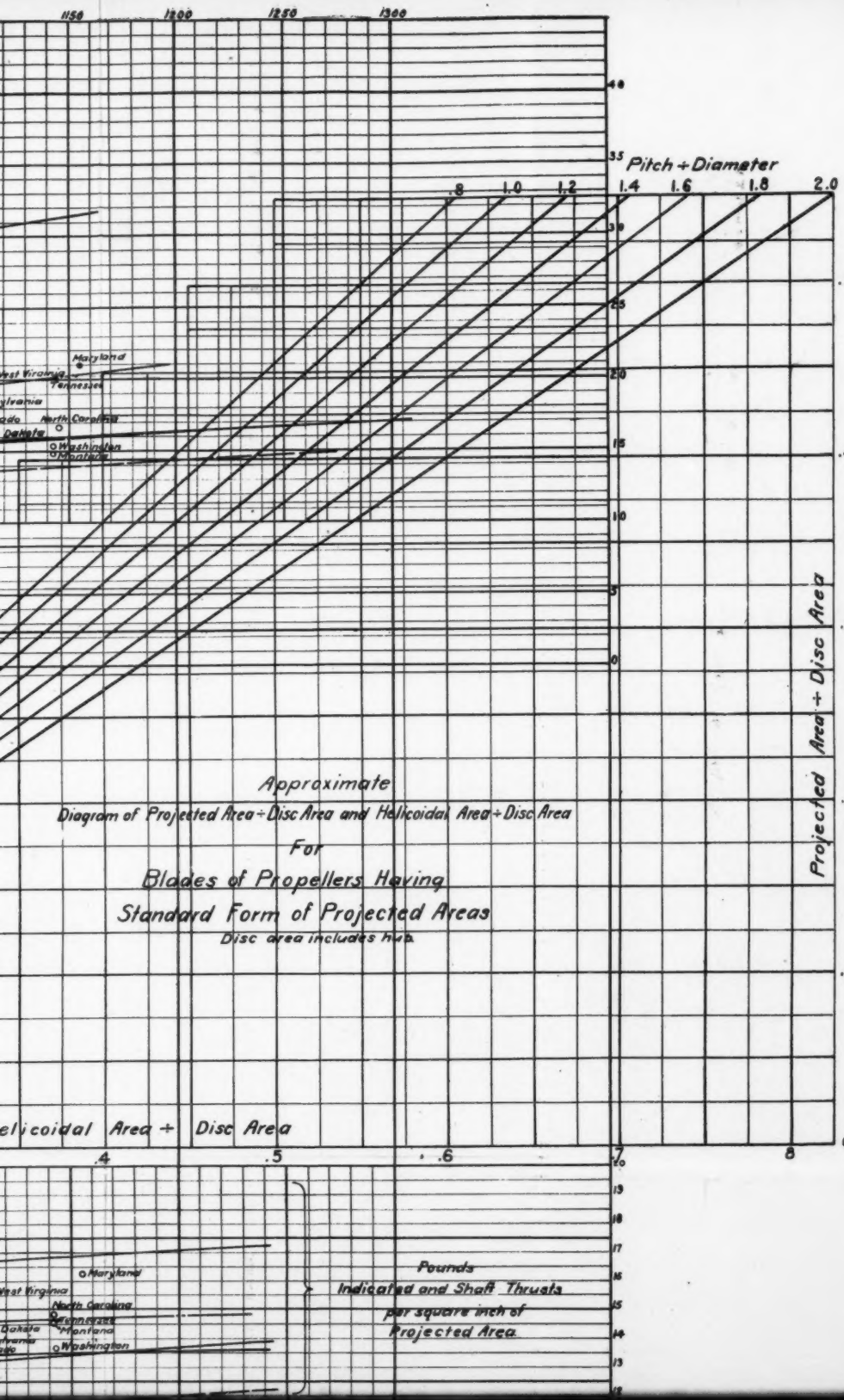
forms of Projected Areas
ppeller Blades.

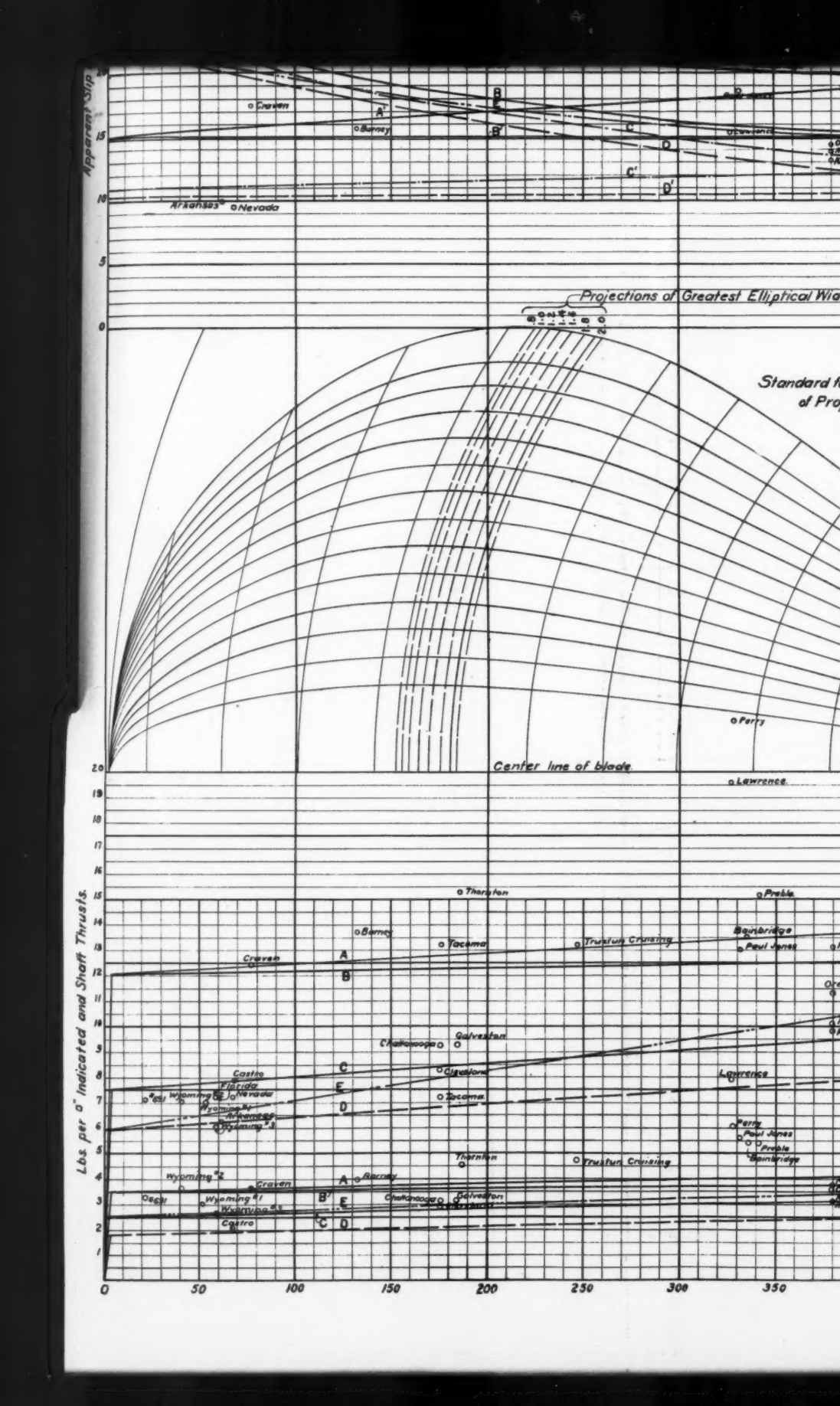
Projected Area Inclosed by Curve.	Ratio of Projected to Disc
1	.096
a	.126
a'	.159
2	.187
b	.218
b'	.250
3	.282
c	.312
c'	.344
4	.373
d	.403
d'	.433
5	.464
6	.509



Truxtun
Virginia
A
Nebraska
Massachusetts
Missouri
Kansas
Olympic Georgia
E
Minnesota
New Hampshire
B
Wisconsin
New Jersey
Vermont
New York


750
800
850
900
950
1000
1050
1100
A
New York
Charleston #2
Charleston #1
St Louis
Brooklyn
Birmingham
Milwaukee
E
B
C
D
0
.1
.2
.3


1150
1200
1250
1300
Pitch ÷ Diameter
.8
1.0
1.2
1.4
1.6
1.8
2.0
40
35
30
25
20
15
10
5
0
.5
.4
.3
.2
.1
0.
Projected Area ÷ Disc Area
Maryland
Tennessee
Washington
Approximate
Diagram of Projected Area ÷ Disc Area and Helicoidal Area ÷ Disc Area
For
Blades of Propellers Having
Standard Form of Projected Areas
Disc area includes hub
elicoidal Area ÷ Disc Area
.4
.5
.6
.7
.8
Maryland
North Carolina
Tennessee
Montana
Washington
Pounds
Indicated and Shaft Thrusts
per square inch of
Projected Area.


Apparent Slip
Lbs. per 0° Indicated and Shaft Thrusts.
Projections of Greatest Elliptical Wid
Standard
of Pro
Center line of blade
Craven
Barney
Arkansas
Nevada
Perry
Lawrence
Thornton
Proble
Bainbridge
Paul Jones
Tacoma
Trustun Cruising
Galveston
Chattanooga
Castro
Florida
Wyoming #1
Wyoming #2
Wyoming #3
A
B
C
D
E
A'
B'
C'
D'

Widths.

d forms of Projected Areas
Propeller Blades.

Projected Area Inclosed by Curve.	Ratio of Projected to Disc
1	.096
a	.126
a'	.159
2	.187
b	.218
b'	.250
3	.282
c	.312
c'	.344
4	.373
d	.403
d'	.433
5	.464
6	.509

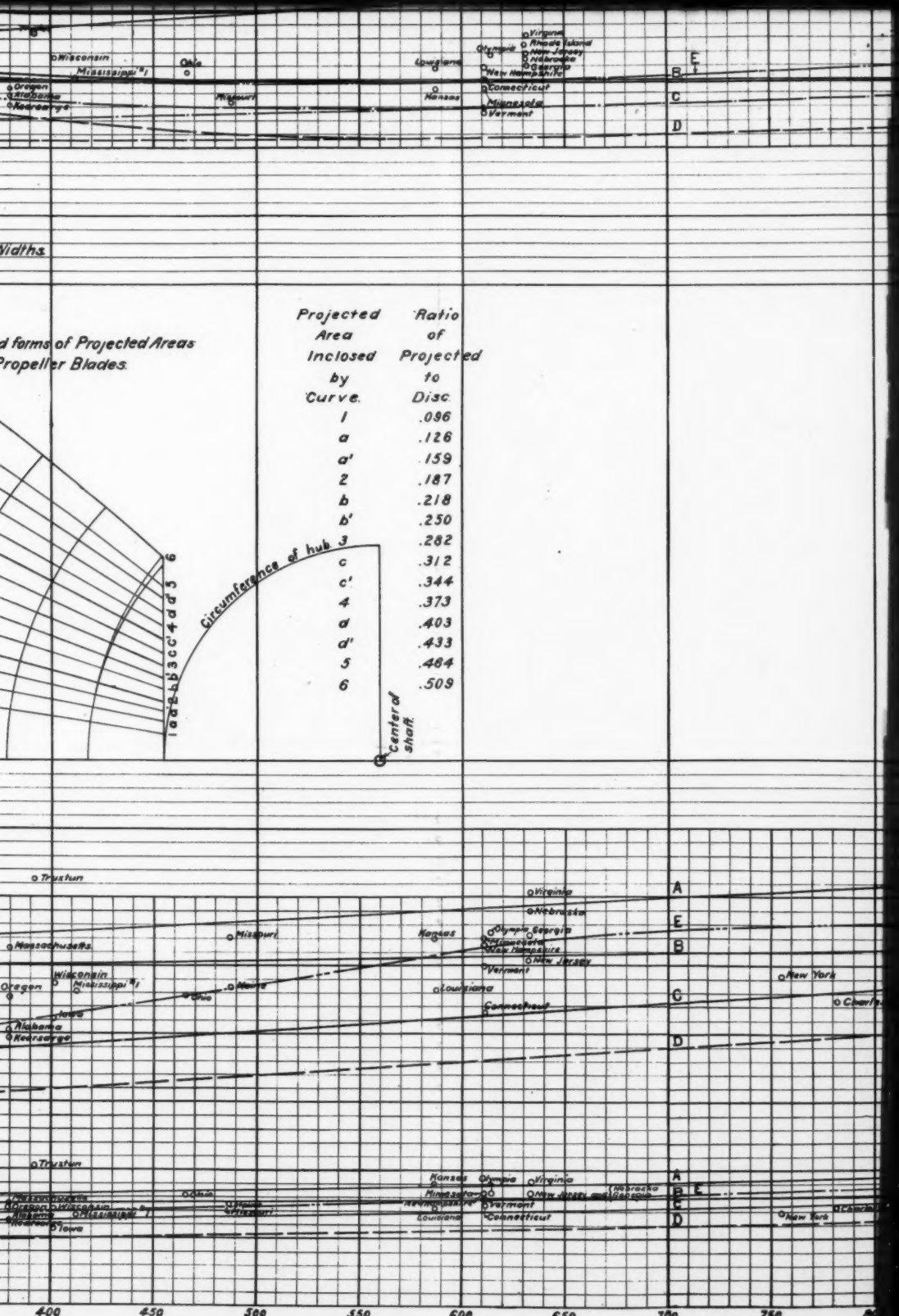


CHART 1.

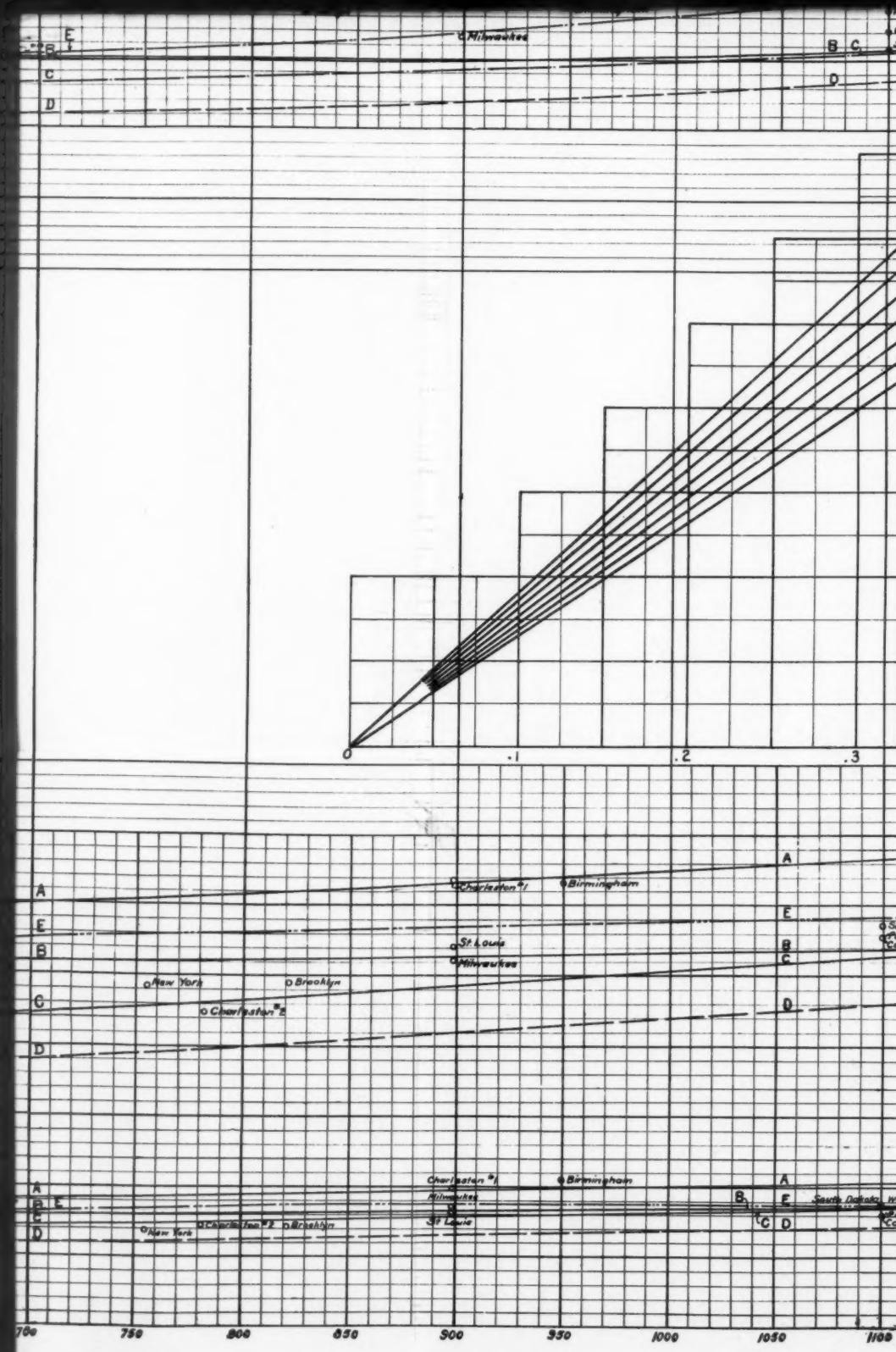
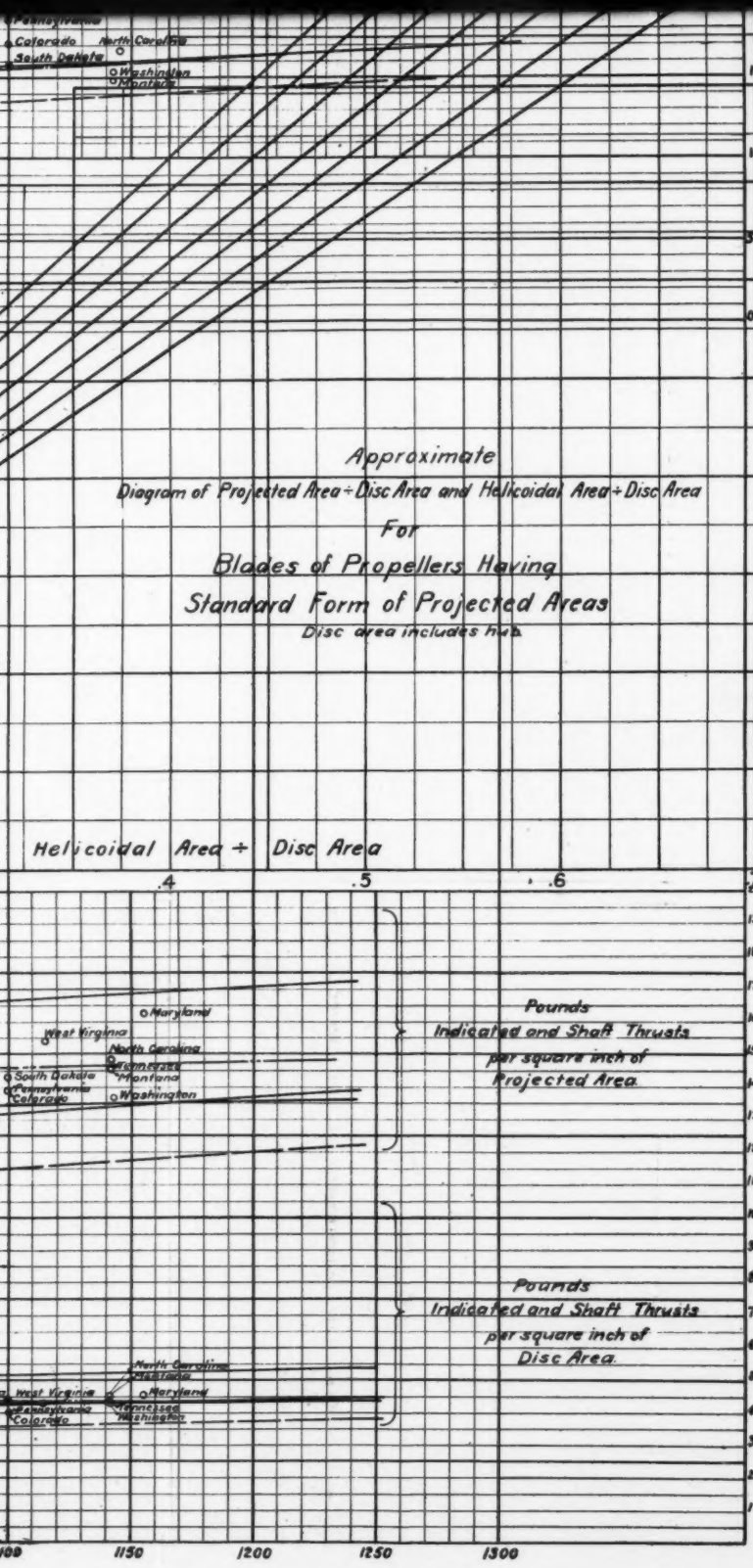

Milwaukee
A
E
B
C
D
0
.1
.2
.3
Charleston *1
Birmingham
St Louis
Milwaukee
New York
Brooklyn
Charleston *2
700
750
800
850
900
950
1000
1050
1100

CHART 1.


Approximate
Diagram of Projected Area ÷ Disc Area and Helicoidal Area ÷ Disc Area
For
Blades of Propellers Having
Standard Form of Projected Areas
Disc area includes hub
Helicoidal Area ÷ Disc Area
.4
.5
.6
Projected Area ÷ Disc Area
.4
.3
.2
.1
0
15
10
5
0
7
8
Colorado
North Carolina
South Dakota
Washington
Montana
Maryland
West Virginia
North Carolina
Montana
South Dakota
Pennsylvania
Colorado
Washington
Pounds
Indicated and Shaft Thrusts
per square inch of
Projected Area
Pounds
Indicated and Shaft Thrusts
per square inch of
Disc Area
North Carolina
Montana
West Virginia
Maryland
Pennsylvania
Tennessee
Colorado
Washington
1150
1200
1250
1300

The thrusts were low, nearly on C for disc and slightly above C for projected area. The slip was high, however, and upon examination of Fig. 33 we see that these propellers were considerably narrower at tip and broader towards hub than those of the standard form or the *Kearsarge*. The standard-form blade of the same developed surface as those of the *Iowa* would have given greater projected surface, lower thrust per square inch of projected area, and less slip.

Battleships Maine, Missouri and Ohio.—See Plates 8-10, see Figures 23, 24 and 25.

Of these three vessels the performance of the *Missouri* was the best. Her indicated thrust per square inch of projected area was quite high, but that per square inch of disc area plotted slightly lower than the B line, while the slip plotted on the C curve. The blade form is slightly broader at the tip than the standard. The *Maine's* propellers evidently lacked in diameter, this lack resulting in a high slip. Her blades are of standard form, but on account of lack in diameter should have been broadened at the tip. The thrust per square inch of disc of the *Ohio's* propellers was quite high, and this, in connection with the narrow-tipped blade form, resulted in a higher slip than that of the *Missouri*.

In the reported trials of these three vessels, if the results of the *Maine* are considered, the differences found are irreconcilable. These propellers had more surface, 2 inches less pitch and less diameter than those of the *Missouri*, yet for the credited speed of 18 knots the speed of revolution and slip increased abnormally over that of the *Missouri*. The curve of propulsive coefficients is also rising rapidly at this speed. The entire results of the *Maine's* trial should be regarded as doubtful.

There is one explanation for the performance of the *Maine* which may possibly be accepted as explaining the discrepancies. The blades of the *Maine* were designed for 19 feet pitch, but on trial were set at a pitch of 18 feet, which would have the effect of making the pitch of the blade decrease radially from the hub to the tip, so that the pitches at each radius beyond the 45-degree pitch angle would be less than

18 feet, this deviation growing greater as we approach the tip. This would result in making the mean pitch of the more efficient part of the blade less than 18 feet, would considerably raise the indicated thrust figures above those plotted on the chart and would decrease the slip, but not to the degree necessary to bring it down to line B, thus indicating a lack of diameter in the propellers fitted.

Battleships Georgia, Nebraska, Rhode Island and New Jersey, Virginia.—See Plates 11-15, see Figures 26, 27, 28 and 29.

Among these vessels the *Nebraska* was credited with the best performance, but her curves of propulsive coefficients show a sudden and unaccountable rise between 18 and 19 knots, while the slip and indicated thrusts show a decided decrease in the rate of increase.

Of the other vessels the order of their performances is: *Georgia, Rhode Island, New Jersey* and *Virginia.* The propellers of the *Rhode Island* and *New Jersey* are supposed to be identical. The indicated thrusts per square inch of projected area for the first three named plot closely around line B, the *Virginia* and *Nebraska* plotting well above it, close to line A. For indicated thrust per square inch of disc area the first named three and the *Nebraska* plot almost exactly on line B, while the *Virginia* plots close above line A. The plotted slips show the *Georgia* most nearly on line B, with the *Nebraska* just above, closely followed by the *New Jersey* and *Rhode Island,* the *Virginia* plotting close to line A. At cruising speeds the blades of the *Nebraska* and *Georgia* reach a greater maximum propulsive coefficient than the others, although the showing of the *New Jersey* and *Rhode Island* are very good. The propellers of the *Virginia* were too small in all respects—pitch, diameter and surface.

In blade form the *Virginia's* blades were narrower towards the tip and wider at the hub than the standard form, as were also those of the *Nebraska.* The blades of the *Georgia, New Jersey* and *Rhode Island* differed in the other direction, being narrower towards the hubs and broadened at the tips. The

blades of the two last-named vessels were so narrow at the roots for the surface carried as to lead to a suspicion that change of form under high thrusts may have occurred, as in the case of the *Vermont*, although the performance curves do not indicate such change. The blades of the *Nebraska* show a better ratio of thickness to width at the hub than those of the other vessels.

Battleships Connecticut, Minnesota, New Hampshire, Louisiana, Kansas, Vermont, Michigan and South Carolina.—See Plates 16-21, see Figures 10, 12, 13, 14, 15, 16.

Of these vessels, the *Michigan* and *South Carolina* yet remain to be tried. Of the others, the showing of the *Connecticut* was slightly better at maximum speed than that of the *Minnesota*, though for speeds below 16½ knots the propellers of the *Minnesota* are much the better; also the maximum efficiency attained by the latter vessel's propellers was much greater than that attained by any other vessel of the class. This excellent showing of the *Minnesota's* propellers is hard to explain, as they are supposed to be practically duplicated in those of the *Louisiana* and *New Hampshire*, which failed to show anywhere near the same propulsive coefficients. The only existing difference in the propellers that can be found is the fact that the mean pitch of the *Minnesota's* propellers is about .6 inch greater than that of her sisters', a difference hardly large enough to account for the discrepancies in the performances. The propellers of the *Louisiana* turn inboard, which, according to prevailing belief, tends to a slight increase in efficiency of propulsion; this increase, however, is not found in this case.

The propellers of the *Vermont* follow in propulsive coefficient those of the *New Hampshire*. These propellers have very wide blades, narrow at the roots, and the appearance of the slip and thrust curves indicates a change of pitch of the blades under high thrusts, to a lower pitch in fact, which would decrease the plotted slip and increase the indicated thrusts.

The propellers of the *Kansas* were very extravagant in power, and the reasonable explanation for this extravagance is

in the form of blade section at the root, combined with too little diameter for the pitch carried, but the blade section was probably paramount, as it probably increased the true pitch of the blade much above the nominal pitch, giving an abnormally high (true) apparent slip, the section also probably tending to waste a large percentage of power in blade eddies at the root.

In blade forms that of the *Connecticut* departs most widely from the standard, while those of the *Michigan, Minnesota, New Hampshire, Louisiana* and *South Carolina* approximate very closely to it, the *Michigan* having almost exactly the standard form, while the other four vessels are slightly broader at the tip, a very good difference in their cases, as the diameters are all small. The blades of the *Kansas* do not depart widely from the standard, though they approximate more closely to an ellipse.

Those of the *Connecticut* may be considered as having the surface badly placed, resulting in more weight than necessary, a higher speed of rotation and a higher slip than were required to obtain as good, if not better, results with a propeller of smaller developed surface but the same projected surface.

Using the horsepower of the *Connecticut* and 125 revolutions for 18½ knots, and figuring out for thrusts and slip for the *Michigan* and *South Carolina,* we find the *Michigan* having slightly lower indicated thrusts and slip than the *South Carolina,* the points of thrust for the former plotting slightly below the B lines, while that of the *South Carolina* for disc-thrust plots slightly above it. The slips are slightly higher in both cases than the B line of slip. This would seem to indicate a lack of diameter in the case of the *South Carolina,* and that, everything else being equal, we can expect the better results from the *Michigan's* propellers.

Protected Cruiser Olympia, Armored Cruisers New York and Brooklyn.—See Figures 31, 32 and 38.

None of these vessels were standardized for speed before their acceptance trials, and on those trials were run back and forth over a forty-mile course. As in the cases of other vessels

similarly tried, the results show an abnormally high propulsive coefficient in each case, as will be seen by referring to Table II. However, the propellers in any case did not give much below the speed credited, and we can plot the points of thrust and slip in their approximate positions on Chart 1. The *New York's* and *Brooklyn's* propellers both indicate ample disc areas, as the indicated thrusts per square inch of disc plot below the C line, while the projected surface in both cases appears to be ample, the points for thrust per square inch of projected areas plotting slightly above the C line. The slip of the *New York* is abnormally high, while that of the *Brooklyn* is also high. The propellers of the *Olympia* appear to have lacked slightly in disc area and also in projected area, although this latter is not so important. The slip was also higher than it should have been.

The high slips in all three cases were probably due in a great degree to the blade forms and to the blade sections used. The blade forms are all broader near the hubs and considerably less in width toward the tips than the proposed standard, while the blade section is one which, with few exceptions, returns low thrusts and comparatively high slips for those thrusts.

Protected Cruisers Charleston, St. Louis and Milwaukee.—See Plates 35-38, see Figures 39, 40, 41, 42.

According to trial reports, the order of standing of the propellers of these vessels was *Milwaukee, St. Louis, Charleston* No. 2 and *Charleston* No. 1.

The performance of the *Milwaukee* is, however, doubtful, as we again find the suspicious rise of propulsive coefficients as we approach the maximum speed reported. However, the *Milawukee* did equally as well as the *St. Louis* and probably a little better. The indicated thrusts of these two vessels are very close together, but the slip of the *St. Louis* was very much greater than that of the *Milwaukee,* due to the peculiar trailing form of blade, combined with narrow root and form of blade section. The blade forms, as shown in Figs. 41 and 42, depart very little from the standard forms, they being slightly broader at the tips than the standard.

The first blades fitted to the *Charleston* were too small in disc and in projected area, while the slip was very high. In the second blades the disc and projected area were corrected, but the slip still remained high. Both of these blades differed from the standard form and resembled other higher slip propellers in having the blades narrower at the tip and broader in closer to the hub than the standard forms.

Scout Cruiser Birmingham.—See Plate 63. See Fig. 43.

The results obtained with these propellers appear to be fairly good, but improvement should be possible. The indicated thrusts per square inch both for projected and disc area are larger than they should be for first-class results, while the slip appears to be too high. To improve results a slightly greater diameter, larger projected area, with a decrease of pitch, appears to be what is necessary. The *Birmingham's* blade form was much narrower at the hub and considerably wider at the tip than the standard form, and this variation may have slightly improved results on account of the lack of diameter. The blade at the root appears very heavy, which may have reduced the efficiency somewhat.

Armored Cruisers Pennsylvania and Colorado, Maryland, West Virginia, California and South Dakota.—See Plates 24-29. See Figures 44, 45, 46, 47.

The best results obtained by these vessels were those of the *Colorado* and *Pennsylvania,* although the high propulsive coefficients recorded are open to doubt. The propellers of the two vessels are identical. The indicated thrusts per square inch of projected area fall slightly above line B, but below E, while those per square inch of disc fall below line C. The slip appears higher than it should be, but is below line E. This high slip may be due to the shape of blade section. The blade forms approximate closely to the standard form, but are slightly narrower at the tips.

The next blades in order of propulsive efficiency were those of the *West Virginia,* followed closely by those of the *Maryland.* These blades were identical, but those of the *West Virginia* were set at 6 inches less pitch than those of her sister

ship. By lowering the pitch of the propellers the slip and indicated thrusts appear to have been lowered slightly, and a slight gain in propulsive efficiency resulted. The blade forms of these propellers differed slightly from the standard form, being narrower at the tips, while they appear unduly heavy at the roots.

The propellers of the *South Dakota* and *California* were alike in all respects. The blade forms approximate closely to the standard form, but for the pitch they carried the diameter and surface were too small, as will be seen by an inspection of Chart 1, both indicated thrusts being higher than they should have been. The blade section at the root is peculiar, and may possibly have had some effect in reducing efficiency.

U. S. Armored Cruisers Washington, Tennessee, Montana and North Carolina.—See Plates 30-34. See Figures 48, 49, 50 and 51.

The propulsive efficiencies of these vessels at 22 knots are in the same order as the names of the vessels. For cruising speed, however, the *Tennessee* tops the list and probably the *North Carolina* second, with the *Washington* bringing up the rear. The slip of the *Tennessee* was comparatively high as compared with the other three; the indicated thrusts per square inch of projected area of the *Tennessee, Montana* and *North Carolina* vary little from line E, while that for the *Washington* is on line B. The thrusts per square inch of disc area for the *Tennessee* and *Washington* both fall on line C, while the other two plot above it.

The blade form of the *Tennessee* conforms exactly to that of the standard, while the blade section is that one which appears to tend toward high slips.

The blades of the *Montana* and *North Carolina* are similar, but those of the *Montana* are set at 9 inches less pitch than those of the *North Carolina,* this change in pitch keeping approximately the same indicated thrusts as before the change, but decreasing the slip. The blades are narrower at the tips than the standard form. Fig. 49 shows new blades fitted to the *Montana.* These blades are broader at the tip than the

original blades and than the standard, and are reported to be much smoother running than the old ones. They give practically the same projected area as the old blades, with considerably less developed area.

The blades of the *Washington* follow closely the standard form, but are broader at the tip. They were originally made for an 18-foot 6-inch diameter, but were cut down, thereby, very probably, reducing their propulsive efficiency. They carry the same abnormal blade section as the *Kansas,* and probably lost in efficiency from this cause.

Turbine Vessels Creole, Salem and Chester.—See Plates 65-74. See Figures 1, 2, 3, 5, 6, 7, 8, 11.

In speaking of the propulsive efficiency of turbine propelled vessels the term must not be considered as meaning the same as when applied to reciprocating engine propelled vessels. In the first case it is the ratio between the effective horsepower and the shaft (meter) horsepower, while in the latter it is the ratio between the effective and the indicated horsepowers. If in place of the indicated horsepower in the latter case the shaft horsepower were measured and used, the propulsive coefficients resulting would be immensely superior to those shown by the best turbine propellers of which we have any record, even to those shown by the best propellers of the *Salem,* which are considered to have been phenomenally efficient.

S. S. Creole.—See Plates 70-74. See Figures 1, 3 and 5.

The first trials of this vessel were made with propellers having the projected form of blade shown in Fig. 1. These blades were very long and narrow and were thick as compared with their width. The blade section at the root was as shown in the same figure, and this section was retained for a considerable distance toward the tip. The first trial was unsatisfactory. The pitch of the blades was then reduced and the trial rerun. The results were slightly improved, but were still very unsatisfactory. These propellers were four-bladed, with detachable blades. The vibrations were excessive, the slips extremely low, showing a heavy negative slip at low speeds, and the speeds of revolution were lower than would be expected with

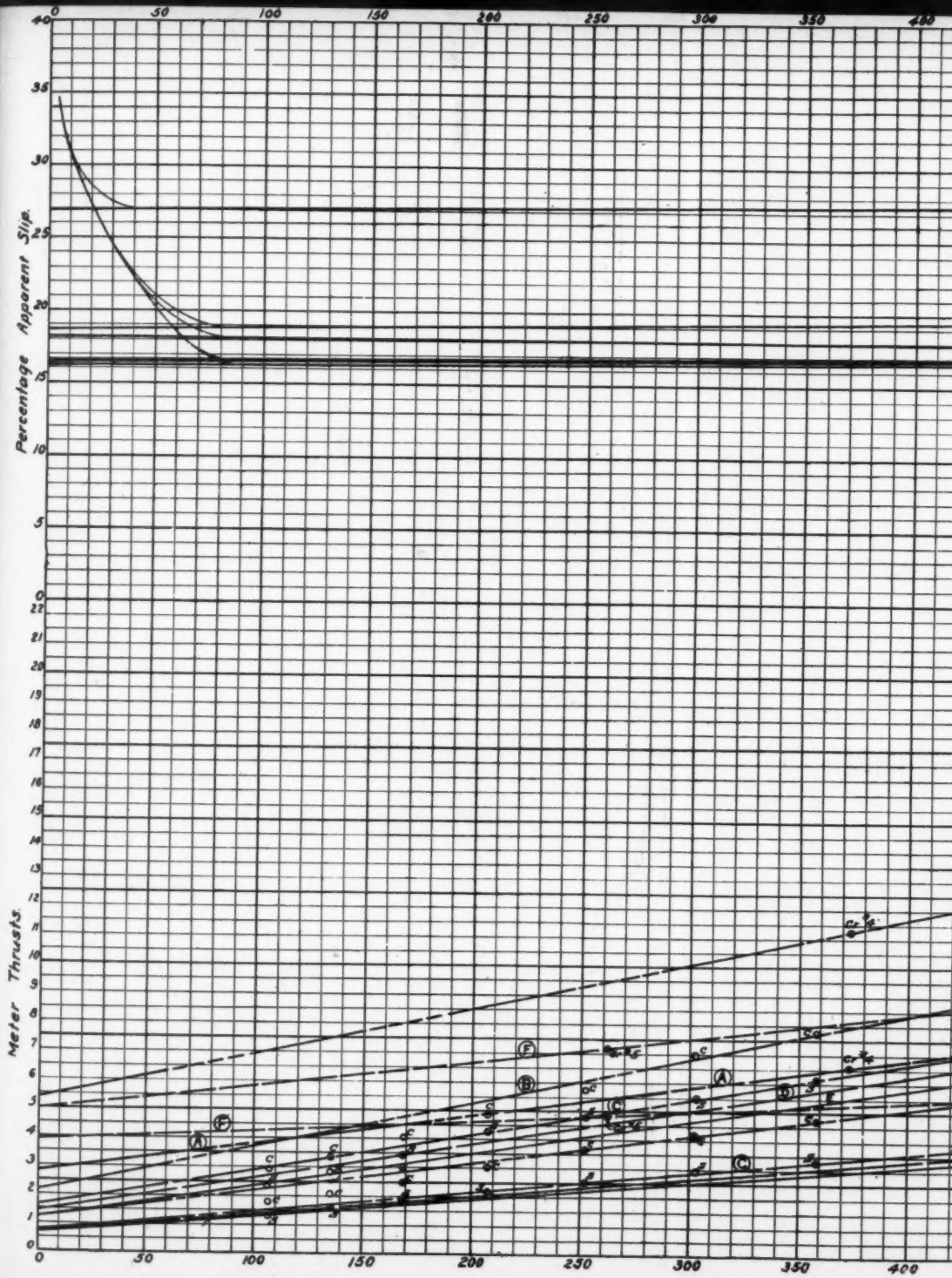

Percentage Apparent Slip.
Meter Thrusts.
0
50
100
150
200
250
300
350
400
(A)
(B)
(C)
(D)
(E)
(F)

CHART 2.

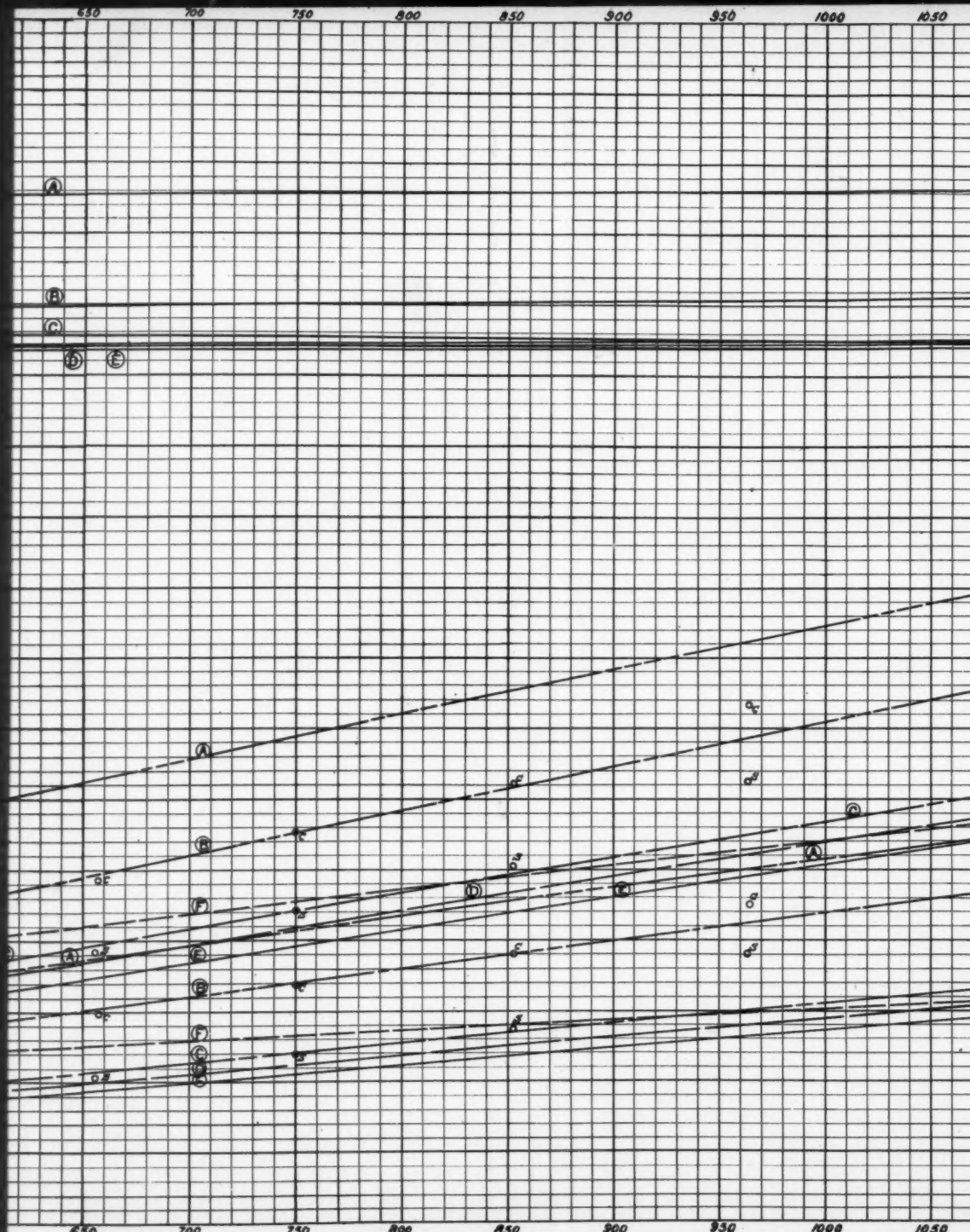
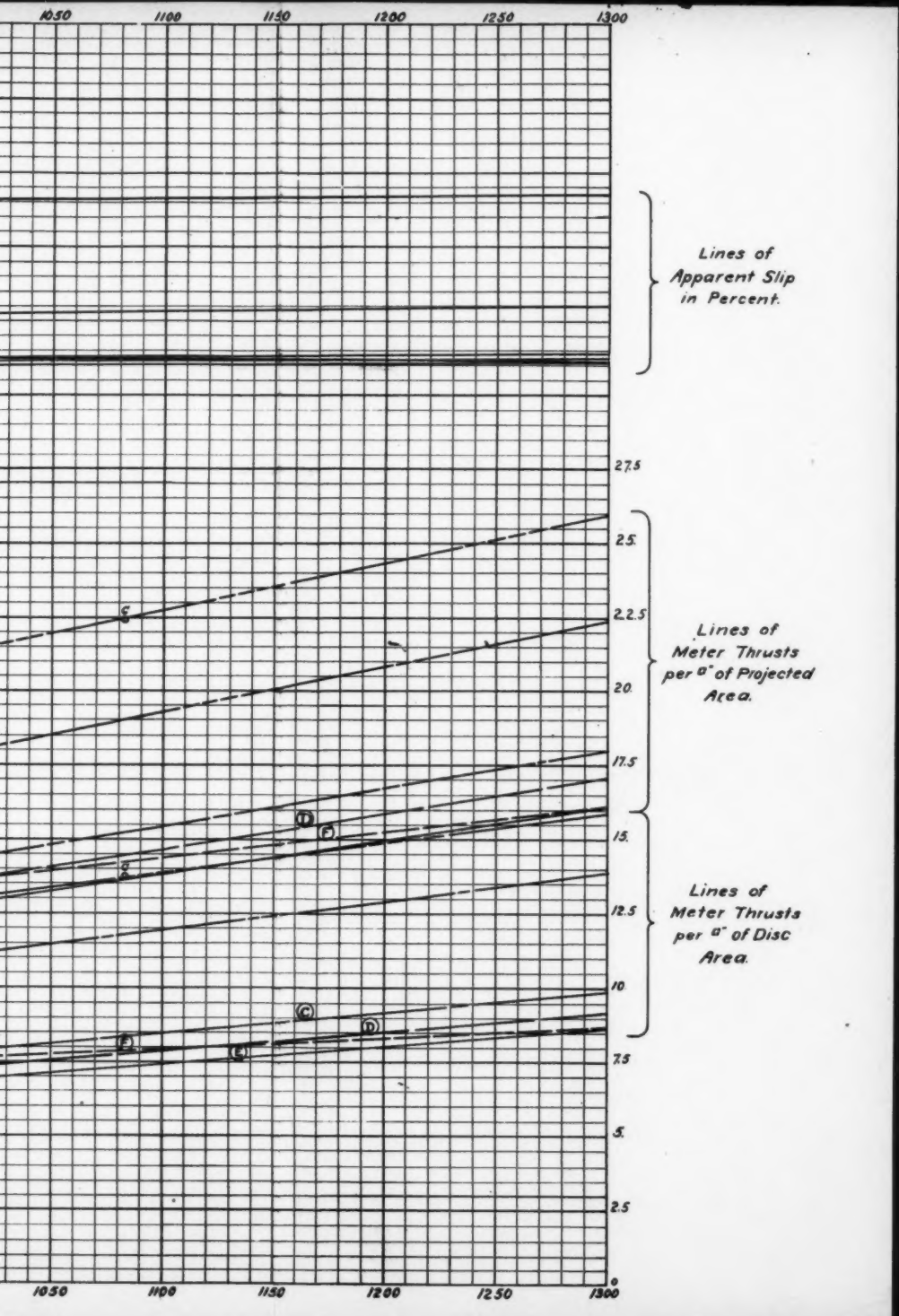

650
700
750
800
850
900
950
1000
1050
A
B
C
D
E
F
650
700
750
800
850
900
950
1000
1050

CHART 2.


1050
1100
1150
1200
1250
1300
Lines of Apparent Slip in Percent.
27.5
25.
22.5
20.
17.5
15.
12.5
10
7.5
5.
2.5
0
Lines of Meter Thrusts per □" of Projected Area.
Lines of Meter Thrusts per □" of Disc Area.
E
D
C
B

the nominally low pitch. The mistakes in these blades probably were as follows: too small surface; four blades in place of three, causing the blades to be narrow and thick on account of the small surface carried; detachable blades, causing the 45-degree pitch angle to fall well within the inside of the hub circumference, by which good propelling pitch surface was lost; and a bad blade section for such narrow blades, by which the true pitch of the blade far exceeded the nominal designed pitch, which latter cause explains the phenomena of negative slip in this case at least.

These propellers were replaced by three-bladed propellers having the projected form and blade section shown in Fig. 3. The results obtained were very much better than the previous ones; the vibrations had practically disappeared, but the meter thrusts were still high as compared with the corresponding thrusts at the same abscissae values, on Chart 2, of the *Salem's* successful propellers.

These propellers were replaced later by those whose projected form and section are shown in Fig. 5. These blades resulted in a still greater, but only to a small amount, increase in efficiency, due to the great increase in surface and the lower resulting meter thrusts per square inch of projected surface. This increase in efficiency was probably much less than it would have been if the thrust per square inch of disc had been kept low.

The performance of the next propeller is based upon unofficial report and may not be strictly correct, but is approximately so. No plans of the propellers themselves are available. The efficiency of propulsion in this case was still further increased. The meter thrusts, both per square inch of projected and disc areas, and the slip were much decreased over those of the preceding propellers. The thrusts obtained are not yet as low as the corresponding ones of the *Salem* on the same abscissae, and the propulsive coefficient is far below that of the *Salem*. It would appear that the lacking necessary feature of the *Creole's* propellers was diameter, in order to lower the disc thrusts per square inch still lower than those already obtained.

Fig. No. 1 blade form is seen to differ very radically; blade No. 3 is wider at the tip, and blade No. 5 slightly narrower in the body and wider at the tip than the standard form.

Scout Ships Salem and Chester.—See Plates 65-69. See Figures 2, 6, 7, 8 and 11.

Of these vessels, the 2d, 3d and 4th sets of propellers tested on the *Salem* were all very much superior to those used on the *Chester,* this superiority being due entirely to the fact that, due to the comparatively slow speed of revolution of the *Salem's* propellers, very much larger disc areas could be used than with the *Chester,* without exceeding the tip speed realized by the propellers of the latter vessels. This increase in disc area caused a much lower meter thrust per square inch of disc area, and in passing through the series of trials of the *Chester's* and *Salem's* propellers, taking the propellers in the order of meter thrusts per square inch of disc, we find that as we pass from the highest values of these thrusts to the lowest value realized the efficiency of propulsion gradually increases. Again, the meter thrusts per square inch of projected area do not appear to be so important as those per square inch of disc in affecting the efficiency, as those of propeller No. 4 were less than those of the best propeller, No. 2, while those of No. 3 were greater. The meter thrust of No. 4 per square inch of disc was higher than those of both No. 3 and No. 2, and its efficiency was less than either. Its slip was approximately the same as that of No. 2. The thrusts and slip of the *Chester's* propellers were higher than any of those in the *Salem.*

The first propeller of the *Salem* had the same blade section as that of the first propeller of the *Creole,* its 45-degree pitch angle fell within the surface of the hub, and we find the same results as experienced with the *Creole's* propeller—low slip, low speed of rotation, high thrusts, low propulsive efficiency and high vibration.

In blade form the No. 2 propellers coincide exactly with the standard, having been taken as the model for the proposed form. Next in order of approximation are those of propeller No. 4, closely followed by those of the *Chester,* both of these

being slightly narrower in the body and very slightly wider at the tips than the standard. The next in order of resemblance are the No. 3 blades, which are much wider at the hub and narrower in body and tip than the standard; the slip of these blades was considerably higher than in No. 2 and No. 4. The widest departure from the standard form is found in the No. 1 blades, Fig. 2, which are much wider close to the hub, narrower in the body and wider at the tip than the proposed standard blade. Results with these blades were much affected by the blade section as already mentioned.

GENERAL CONCLUSIONS.

Effect of Blade Section.—Blade sections similar to those shown in cuts of projected areas for the *Tennessee, Pennsylvania, Colorado, Connecticut* and several others tend, for equal nominal pitches and projected areas with those shown in similar cuts for the *Minnesota, Kearsarge, Ohio, Georgia, Milwaukee* and others, to less indicated thrust per square inch per revolution, to greater speed of rotation and to greater slips. The efficiencies appear to be about the same.

Blade sections similar to those shown in cuts of projected areas for the *Creole* No. 1 and No. 2, *Salem* No. 1, *Kansas* and *Washington* seem, especially in narrow and thick blades, to work with a much greater pitch than the nominal pitch, requiring much higher indicated or meter thrusts per revolution than, and reducing the speed of rotation very much below those of, blades having the same nominal pitch and area. The efficiency of propulsion is very much reduced, although all of these evil effects seem to decrease, if not entirely disappear, when the blade at the root has a small value of thickness divided by width, even though this shape of section be retained.

The blade section shape at the root as shown for the *Missouri* appears to give as good results as may be looked for, but this may possibly be slightly improved by shifting the line of greatest thickness slightly from the center line of the blade towards the leading edge in order to give a finer run of the

back of the blade towards the leaving edge, and by fining the leading edge at the fillet, as shown in the *Milwaukee's* section.

All of the sections shown are with the blade fillets omitted.

Blade Form.—The figures showing the projected areas of the propellers discussed, together with the equivalent proposed standard forms of equal projected areas, show that the majority of the best performances were made by blades closely approximating in shape to this form, and that if any departure from this form be made it should be in the direction of narrowing the blade in the body and broadening at the tip, where the conditions of design are such as to prohibit the use of the diameter determined by Chart 1 to be desirable. This modification should not be carried to the point of making the blade triangular. It should in this case become an oval, with the outer end very much more flattened than the proposed standard form oval.

Thrusts Per Square Inch of Projected and Disc Areas.—Amount of the first can be varied between quite wide limits without seriously affecting the efficiency. An increase in its value will mean a corresponding increase in slip and vice versa. As the thrust per square inch of disc area slowly increases above that called for by Chart 1, the thrust per square inch of projected area must decrease very rapidly in order to hold efficiency and prevent too great an increase in slip.

Slip.—May vary within quite wide limits and efficiency still be maintained. It, however, depends on diameter and projected area and blade section and form, and these should be so proportioned as to hold it down to the more desirable lines of design shown on Chart 1.

PLATES 1 TO 75.

These Plates, deduced from the performances of the various vessels considered, show in curves 1, 2 and 3 the indicated or meter thrusts in pounds per square inch of disc, helicoidal and projected areas, the area of the hub being included in that of the disc. Curves 4 and 4° are the curves of propulsive coefficients, no attempt having been made to fair them. Curves 4 are for

the propulsive coefficients when the models have been towed with appendages, and curve 4ª when towed without them. Curve 5 is the curve of apparent slips and curve 6 that of speeds in knots per hour. The abscissae for all of these curves are expressed as tip speeds in feet per minute.

Among these Plates are one each for the *Maryland* and the *West Virginia* at cruising draught, the effective horsepower used in obtaining the propulsive coefficients being the effective horsepower at the draught given as the trial draught of these vessels in Table II. A similar curve, with propulsive coefficient obtained in the same way, is also given for the *Virginia*. Another plate of performances is given for the *Truxtun* at cruising draught, but in this case the effective horsepower used in obtaining the propulsive coefficient is obtained from the effective horsepower curve of the model towed at a corresponding draught and displacement.

Table II.—In this table are given the principal characteristics of the vessels and their propellers which have been discussed; the noted propulsive coefficients for speed realized in some cases and for contract speed in others, with the indicated or meter thrusts realized for these speeds, slips and propulsive coefficients.

CONCLUSION.

In the foregoing work all theoretical points of discussion have been carefully refrained from, and the items discussed are those which it is considered practice has fully demonstrated as facts. It is not claimed that by following the above suggestions and the accompanying chart that the best possible propeller for any particular ship, power and speed will be obtained, but it is claimed that the resultant propeller will be as good as our average ones, and possibly better. The principles of propeller design have not reached such an advanced stage as to enable us to sit down and figure out a propeller for any desired conditions which we can guarantee will do the best that can be done under those conditions. In all theoretical works on propellers and propulsion, in the formulae for design are incor-

TABLE 2.

DIMENSIONS OF HULLS AND PROPELLERS, WITH APPROXIMATE PROPULSIVE COEFFICIENTS, APPARENT SLIPS AND THRUSTS PER SQUARE INCH.

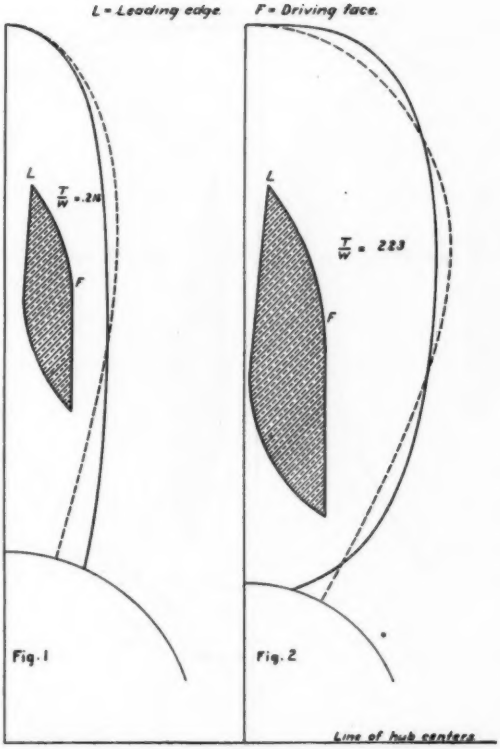
Name.	Hull.						Speed at point plotted on charts.	Propulsive coefficients.		Propellers.								Indicated or meter thrusts per sq. inch.		
	L. W. L.	Beam.	Mean draught.		Displacement.	Block coefficient.		Without Appendages.	With Appendages.	Number.	Blades, One.	Diameter.		Pitch.		Helicoidal area.	Projected area.	Slip.	Helicoidal area.	Projected area.	Disc area.
	ft.	*ft.*	*ft.*	*ins.*	*tons.*			*p. ct.*	*p. ct.*			*ft.*	*ins.*	*ft.*	*ins.*			*p. ct.*			
Massachusetts	348 0	69.25	24	10½	10,555.	.622	16.7	52.2	...	2	3	15	6	16	0	53.86	45 24	23.0	10.87	12.94	3.1
Oregon	348.0	69 25	24	0	10,250.	.620	16.8	55.1	...	2	3	15	0	15	6	66.0	55.41	14.33	9.514	11.33	3.55
Iowa	360.0	72.21	24	0½	11,363.	.630	17.087	55.8	...	2	3	16	6	19	6	75 74	60.0	20.93	8.38	10.58	2.85
Kearsarge	368.0	72.21	24	1	11,738.	.644	16.82	53.1	65.1	2	3	16	9	17	3	84 2	69.2	13.11	8.06	9.83	3.08
Illinois	368.0	72.21	24	1	11,738.	.644	17.45	...	71.6	2	3	16	9	17	3	84.2	69 2	13.12	8 47	10.3	3.24
Alabama	368.0	72.21	23	11½	11,734.	.643	17.0	...	71.1	2	3	16	0	17	6	76.0	62.0	14.8	8.5	10.42	3 22
Wisconsin	368 0	72.21	23	11	11,500.	.642	17.174	...	68 2	2	3	15	6	17	6	68.0	57.0	16.68	9.95	11.87	3.58
Maine	388.0	72.21	24	4½	12,755.	.654	18.0	65 1	71.2	2	3	16	0	18	0	79 0	63.0	20 96	9.37	11.74	3.78
Missouri	388.0	72.21	23	6	12,240.	.654	18.145	62.0	72.3	2	3	17	0	18	2½	73.7	62.8	13.3	11.43	13 42	3.70
Ohio	388.0	72.21	23	5½	12,480.	.654	17.82	56.4	62.7	2	3	16	6	17	3	90.0	75.0	15.55	9 50	11.41	4.12
Georgia	435.0	76.21	23	8	14,907.	.656	19.0	54 9	63.0	2	3	18	0	19	2	97.92	77.12	16.16	10.76	13.65	4.14
Virginia	435.0	76 21	23	9	14,978.	.658	19.0	51 4	60.0	2	3	17	3	18	3	84.5	71.0	18.4	12.75	15.17	4.6
Nebraska	435.0	76.21	23	10½	14,900.	.656	19 0	56.0	64 2	2	3	17	9½	19	0.41	89.2	71.7	16.2	11 66	14.5	4.16
Rhode Island	435.0	76.21	23	7½	14,860.	.655	19.0	53.9	61.6	2	3	17	9	18	8	99.2	82.5	17.76	10.56	12.7	4 22
New Jersey	435.0	76.21	23	8½	14,870.	.655	19 0	54 7	62.7	2	3	17	9	18	8	99.2	82.5	17.0	10.56	12.7	4 22
Louisiana	450.0	76 83	24	7	16,033.	.660	18.0	51.0	61.2	2	3	17	3	18	0	84.5	71.5	14.9	9 92	11.64	3.58
Connecticut	450.0	76.83	24	11½	16,377.	.660	18.5	52.2	61.8	2	3	17	9	17	7½	100.8	84.3	14.9	9.15	10 85	3 70
Kansas	450.0	76 83	24	6½	16,075.	.660	18 0	42.0	50.4	2	3	17	4	17	6	99.63	81.71	13.7	10.45	12.75	4 40
Vermont	450.0	76.83	24	5½	15,986.	660	18 5	49 4	58.2	2	3	17	9	18	0	90.57	77.88	12.6	10.8	12.45	3.9
Minnesota	450.0	76.83	24	6½	16,016.	.660	18.5	52.1	62.4	2	3	17	3	18	0.7	84.5	71.5	13.0	11.36	13.4	4.13
New Hampshire	450.0	76.83	24	6½	16,023.	.660	18.5	50.6	59 6	2	3	17	3	18	0	84.5	71.5	15.0	11.3	13.3	4.12
Mississippi	375.0	77.0	24	8½	13,040.	.558	17.0	...	53 8	2	3	16	6	17	0	73.5	62.3	15.0	9.8	11.6	3.35
Mississippi, Second Propeller	...	...	...	...	...	...	...	...	...	2	3	16	0	16	9	76.0	63.86	...	...	...	...
California	502.0	69.5	24	1	13,750.	.558	22 0	48.3	56.3	2	3	18	0	21	6	95.0	78.68	15.6	12.56	15.17	4.68
South Dakota	502.0	69 5	24	1	13,750.	.558	22.0	51 2	59.6	2	3	18	0	21	6	95.0	78.68	15.7	11.86	14.31	4.42
Maryland	502.0	69.5	24	1	13,720.	.558	22.2	52.9	61.3	2	3	17	6	21	6	83.7	67.5	21.07	13.12	16.27	4.57
West Virginia	502.0	69.5	24	1	13,720.	.558	22.15	53.6	61.8	2	3	17	6	22	0½	83.7	68 0	19 95	12.51	15.4	4.35
Colorado	502'0	69.5	23	11	13,670.	.558	22.0	55 2	64.3	2	3	18	0	22	0	92.0	74.0	17 14	11.16	13.87	4.04
Pennsylvania	502.0	69.5	24	1.18	13,817.	.558	22.0	54.1	63.0	2	3	18	0	22	0	92.0	74.0	18.6	11 18	13.9	4.04
Tennessee	502.0	69.5	24	11½	14,480.	.554	22.0	48.5	59.3	2	3	18	0	22	0	92.0	74.0	20.21	11.68	14.53	4 24

Washington	502.0	72.87	25	0	14,495.	.554	22.0	49.5	60.5	2	3	18	0	21	9	98.7	80.72	15.4	11.21	13.71	4.35
North Carolina	502.0	72.87	25	0	14,518.	.554	22.0	46.3	57 5	2	3	18	0	22	6	100.0	78.0	16.13	11.12	14.26	4.37
Montana	502.0	72.87	25	0	14,518.	.554	22.0	48.5	59.3	2	3	18	0	21	9	100.0	79.0	14.9	11.4	14.5	4.5
Montana, Second Propeller	...	...	...	...	...	...	...	...	...	2	3	18	0	21	10	97.5	78.92	...	...	...	...
Milwaukee	424.0	66.0	22	6	9,700.	.539	22 0	56.2	...	2	3	17	0	19	3	90.06	74.7	...	...	...	...
St. Louis	424.0	66.0	22	6	9,665.	.539	22.0	49.6	...	2	3	18	0	19	5½	91.5	76.74	23.6	11.36	13.54	4.09
Charleston	424.0	66.0	22	6	9,710.	.539	22.0	49.6	...	2	3	16	3	20	6	80.0	64.5	25.5	12.83	15.91	4.04
Charleston, Second Propeller	...	...	22	6¼	9,740.	...	21.3	50.9	...	2	3	17	6	20	6	95.0	77.0	23.56	9.82	12.12	3.88
Cleveland	292.0	44.0	15	9	3,200.	.553	16.5	55 5	...	2	3	10	6	11	8.64	34.74	29.6	23.2	7 0	8.30	2.9
Chattanooga	292.0	44.0	15	9	3,156.	.553	16.5	51.2	...	2	3	10	6	11	9	33.7	28.7	22.0	7.85	9 25	3.1
Galveston	292.0	44.0	15	9	3,250.	.553	16.5	48.8	...	2	3	10	6	11	9	34.0	29 0	24.7	7.9	9.25	3.1
Denver	292.0	44.0	15	9	3,200.	.553	16.75	45 3	...	2	3	11	0	11	11	50.26	45.0	27.22	6.10	6.78	3.21
Tacoma	292.0	44.0	15	9	3,250.	.553	16.5	46.0	...	2	3	10	0	11	6	26.79	20.85	34 0	11.4	14.7	3.6
Wyoming, No. 1	252.0	50.0	12	7	3,275.	.719	11.5	...	...	2	3	8	0	8	6	25 8	21.18	33.8	5.1	6 15	2.6
Wyoming, No. 2	252.0	50.0	Cruising foul		bottom.	.719	11.0	...	...	2	3	9	0	7	6	37.2	30 4	23.8	5.3	6.5	3.3
Wyoming, No. 3	252.0	50.0	Cruising foul		bottom.	.719	12.5	Exc	ellent	2	3	9	0	8	6½	39.2	29.5	24.95	4.65	5.8	2.7
Arkansas	252.0	50.0	12	7	3,275.	.719	12.71	...	...	2	3	9	0	7	3	25.6	22.6	9.94	5.39	6.11	2.17
Nevada	252.0	50.0	12	7	3,275.	.719	13.04	...	...	2	3	9	2.7	7	9.55	24.0	21.0	9 53	6.35	7.26	2.28
Florida	252.0	50.0	12	7	3,275.	.719	12.4	...	...	2	3	8	6	8	3⅛	26.0	22.5	24.29	6.15	7.11	2.82
Truxtun	248.5	22.25	6	7¼	490.3	.370	28.5	49.4	...	2	3	8	0	11	3	22 7	17.14	18.25	11.86	15.7	5.35
Truxtun	248.5	22.25	7	7½	619.	.523	26.0	55.0	...	2	3	8	0	11	3	22.7	17.14	23.6	10.5	13.21	4.74
Lawrence	240.8	22.25	6	6½	412.	.404	29.0	41.5	...	2	3	7	4	9	6	21.2	16.9	15.2	15.5	19.35	7.8
Bainbridge	240 5	23.04	7	1⅞	460.	.430	28.5	42.5	...	2	3	8	0	10	7.3	24.9	20.0	20.6	10.8	13.5	5.4
Paul Jones	245.0	23.08	6	10	450.	.410	28.5	49 4	...	2	3	7	5	10	8	24.0	18.6	18.7	10.8	13.01	5.6
Perry	245.0	23.08	6	8½	480.	.410	28 5	40.2	...	2	3	7	5	10	10	16.83	11.9	28.5	15.54	22.0	6.06
Preble	245.0	23.08	7	1¼	435.	.410	28.5	49 4	...	2	3	7	5	10	5	20.33	15.46	21.2	11.54	15.17	5.43
Barney	157.0	17.63	4	9½	168.	.478	27.5	50.3	...	2	3	6	8	10	10.3	14.7	10.0	15.7	9.35	13.7	4.0
Craven	147 0	16.38	4	3½	133.	.448	30.5	62.0	...	2	3	6	5	11	6.5	13.38	8.85	18.3	8.25	12.5	3.5
Thornton	175.0	17.5	5	7½	174.	.383	27 5	61.2	...	2	3	5	8	9	0	10.3	7.59	27.9	11.2	15.25	4.6
New York	380.54	64.83	22	6½	8,480.	.509	21.0	...	62.2	2	3	16	0	20	0	69.09	56.57	24 48	9.93	12.13	3.41
Brooklyn	400.5	64.73	21	10½	8,150.	.520	21.91	...	69.6	2	3	16	6	20	9	75.74	62.37	18.67	10.12	12.29	3.58
Olympia	340.0	53.05	20	8¼	5,586.	.517	21 69	...	68.2	2	3	14	9	19	0	68.0	53.65	16.87	10.73	13.63	4.27
Birmingham	420.0	47.09	16	9½	3,750.	.405	24.0	51.9	56.3	2	3	12	6	15	3 4	49.07	39.3	15.1	11.35	13.7	4.6
50-Foot Launch, 691	50.0	10.0	3	11½	19.77	...	11.36	50.6	...	1	3	3	0	5	0	4.58	3.24	46.0	5.09	7.2	3.3
* *Salem*, No. 2	420.0	47.09	17	5½	4,000.	.407	25.0	57.2	64.8	2	3	9	6	8	8	43.7	38.2	19.5	13.32	15.24	8.21
* *Salem*, No. 1	...	...	16	9½	3,750.	.405	19.0	29.1	32.9	2	3	10	6	7	6	34.0	29.23	12.0	16.9	19.6	6.65
* *Salem*, No. 3	...	...	16	9½	3,750.	.405	25.0	53.0	60.7	2	3	9	0¼	8	3⅛	37.7	33 0	22.8	16.05	18.05	9.5
* *Salem*, No. 4	...	...	16	9½	3,750.	.405	24.5	48.4	55.0	2	4	9	0	8	6	46.62	40.6	19.4	13.70	15.73	10.1
† *Chester*	420.0	47.09	17	3½	3,977.	.407	26.0	46.4	52.0	4	3	6	0	6	0	19.17	17.37	28.37	20.16	22.43	13.77
* *Creole*, No. 1	440.0	53.0	...	...	7,350.	.635	14.75	30.7	...	2	4	11	6	7	2	28 94	25.97	5.5	18.85	21.0	5.25
* *Creole*, No. 2	440.0	53.0	...	...	7,200.	.635	15 0	32.4	...	2	4	11	6	6	6	28.94	26.+	1.5	20.9	22.8	5.7
* *Creole*, No 3	440.0	53.0	...	...	7,390.	.640	16.85	46.9	...	2	4	10	9	8	2	36.0	33.78	16.8	12.4	13.3	4.0
* *Creole*, No. 4	440.0	53.0	...	...	9,700.	.650	17.0	46.6	...	2	3	9	6¼	8	4½	48.0	42.5	27.8	9.9	11.15	6.65
* *Creole*, No. 5	440.0	53.0	...	...	9,700.	.650	15.0	48.5	...	2	3	9	9	7	1½	52.0	50.0	18.0	7.0	7.2	4.85
Castro (Gasoline)	75-33	18.5	5	11½	87.5	.369	10.85	...	...	1	3	5	0	4	10	6.6	5.48	21.88	6.6	7.86	2.22

Creole, No. 5 propeller, is approximate. * Curtis turbines, meter thrusts. † Parsons turbines, meter thrusts.

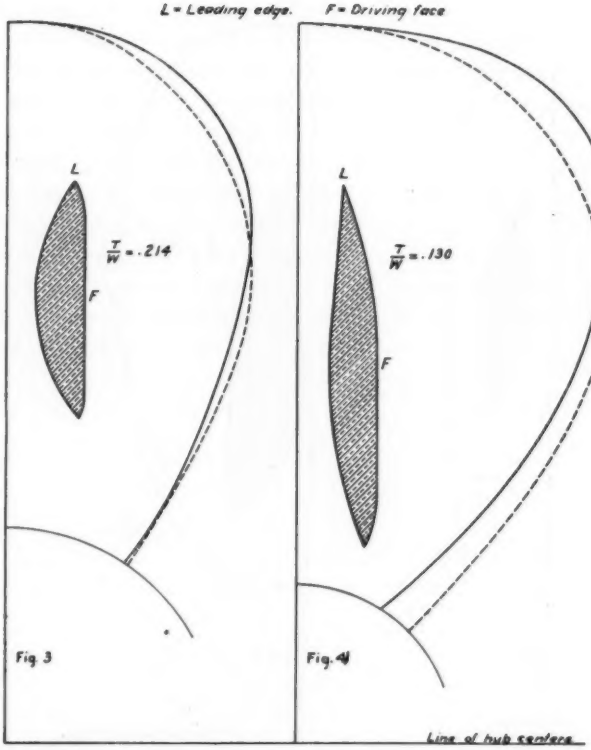
porated so many assumptions and so many guess-work factors, the majority of them based upon model-tank experimental data, data prepared from trials bearing no resemblance whatever to the conditions under which the actual propeller will work, that the results obtained differ but little, if any, from those obtained by the old rule-of-thumb methods.

In this work, while the old argument of varying conditions of wind and sea, poor steering, varying conditions of engines, influence of depth of water on trial, difference in time and variations in initial friction of engines, may and probably will be used against the results obtained, yet such a large number of ships, of such varying conditions as to form, speed and size of hull, have been used that it is considered the results secured are as nearly accurate as it is possible to obtain, and, being so, may be used with safety either in design or in checking up designs.



Creole #1 and #2
$\frac{P.A}{H.A}$ = .837 $\frac{P}{D}$ = .623
Very poor
Turbine (Curtis)

Salem #1
$\frac{P.A}{H.A}$ = .860 $\frac{P}{D}$ = .714
Very poor
Turbine (Curtis



Creole "3

$\frac{P.A}{H.A} = .938$ $\frac{P}{D} = .76$

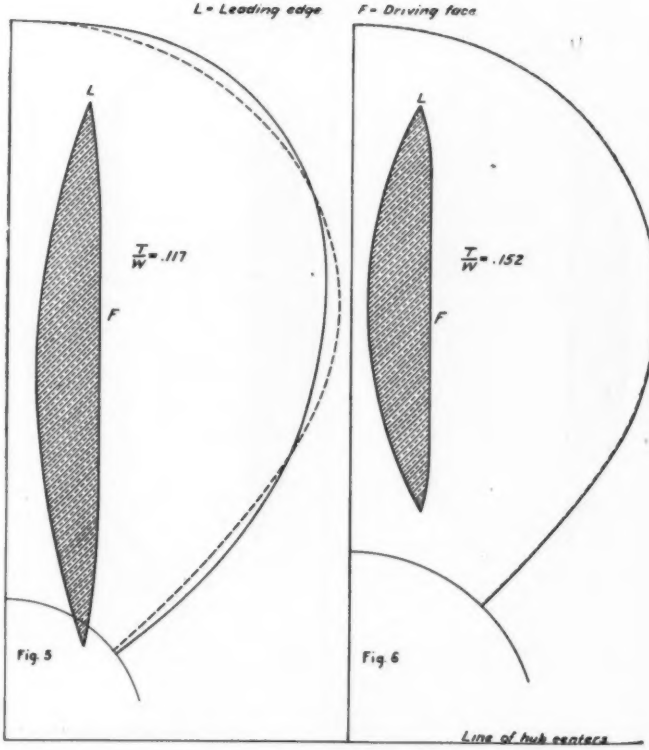
Fair

Turbine (Curtis)

Wyoming (Cheyenne) "2

$\frac{P.A}{H.A} = .817$ $\frac{P}{D} = .833$

Excellent when set to 8ft. 6" pitch.
Slightly decreasing above area.



Creole #4

$\frac{P.A}{H.A}$ = .885 $\frac{P}{D}$ = .863

Results good.

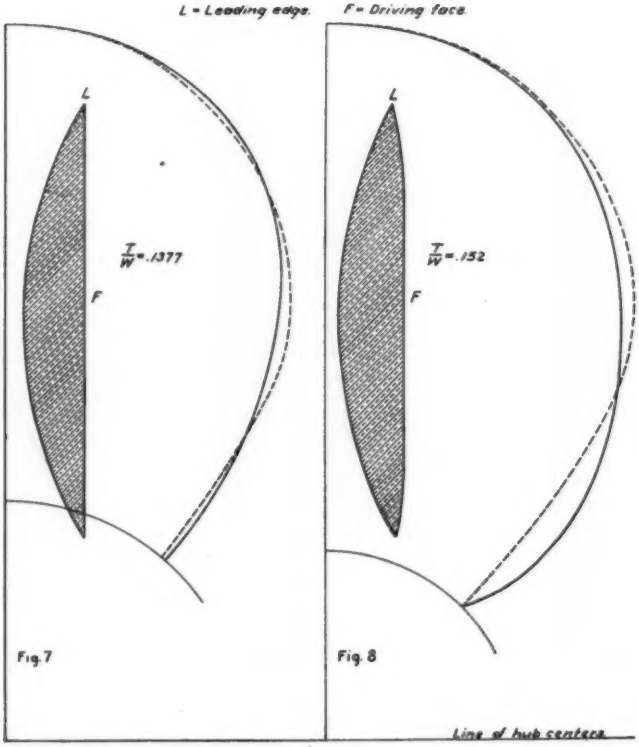
Turbine (Curtis)

Salem #2

$\frac{P.A}{H.A}$ = .874 $\frac{P}{D}$ = .9123

Results excellent.

Turbine (Curtis.)



Salem "4

$\frac{P.A}{H.A}$ = .871 $\frac{P}{D}$ = .944

Results fair.

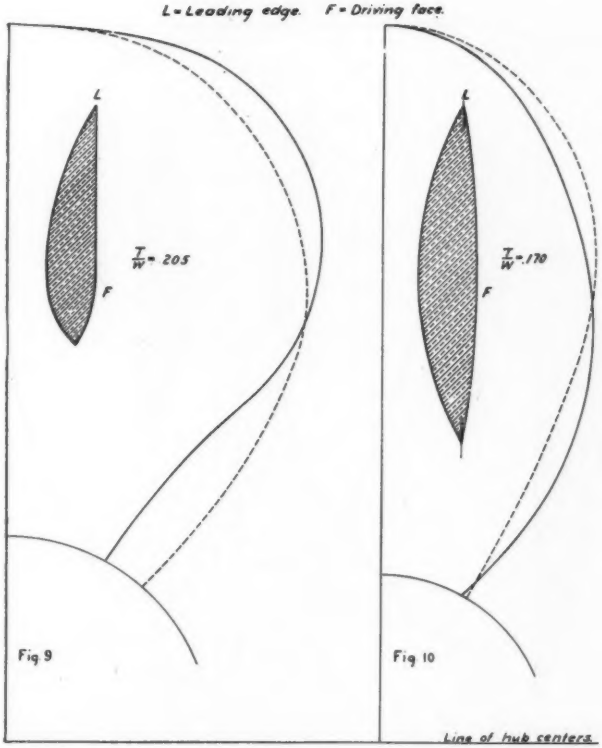
Turbine (Curtis)

Salem "3

$\frac{P.A}{H.A}$ = .875 $\frac{P}{D}$ = .965

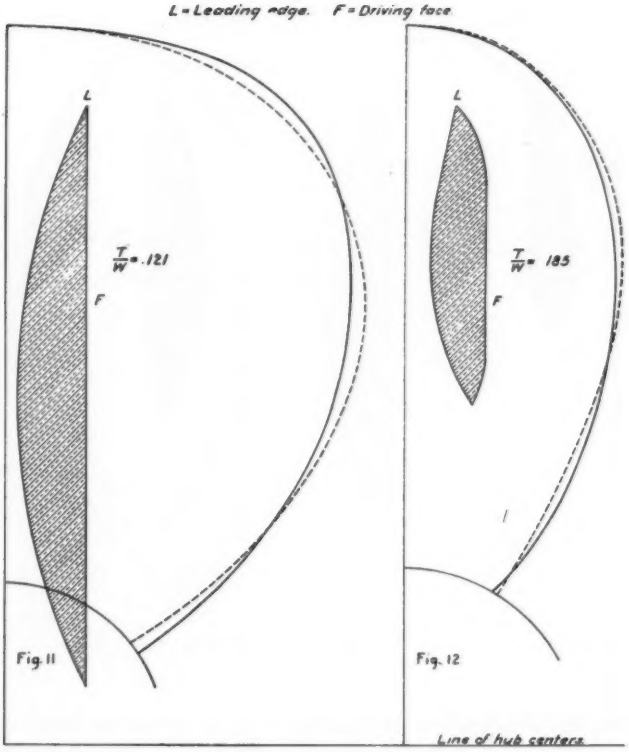
Results very good.

Turbine (Curtis)



Denver
$\frac{PA}{H.A}$ as designed = .90 $\frac{P}{D}$ = .954
P A with 10ft 6" pitch
Pitch set on trial trip 11ft 11"
Results poor, vibration very heavy

Connecticut
$\frac{PA}{HA}$ = 836 $\frac{P}{D}$ = .933
Results excellent.



Chester
$\frac{P.A}{H.A}$ = .92 $\frac{P}{D}$ = 1.0
Results good.
Turbine (Parsons)

Kansas
$\frac{P.A}{H.A}$ = .820 $\frac{P}{D}$ = 1.009
Results very poor.
Abnormally bad blade section.

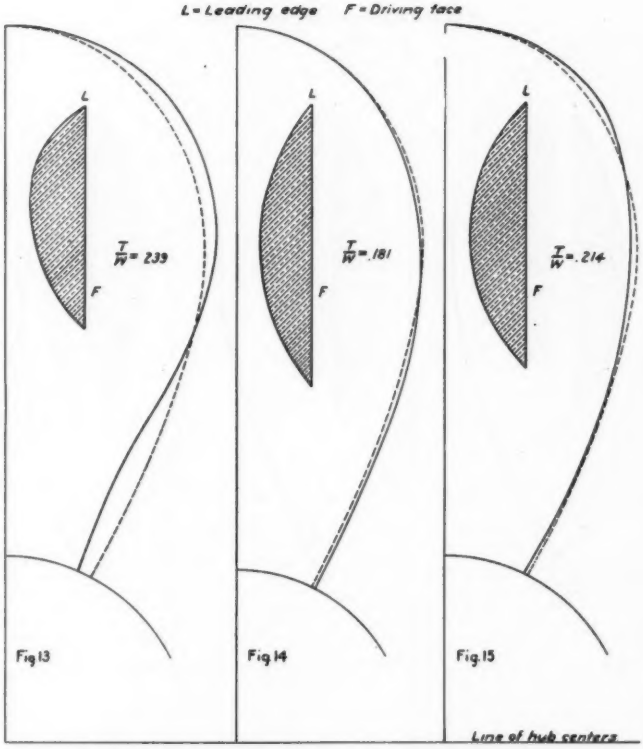


Fig 13

Vermont

$\frac{P.A}{H.A}$ = .860 $\frac{P}{D}$ = 1.014

Results: good

Blade too narrow and thick at hub, Blade sprung

Fig 14

Michigan

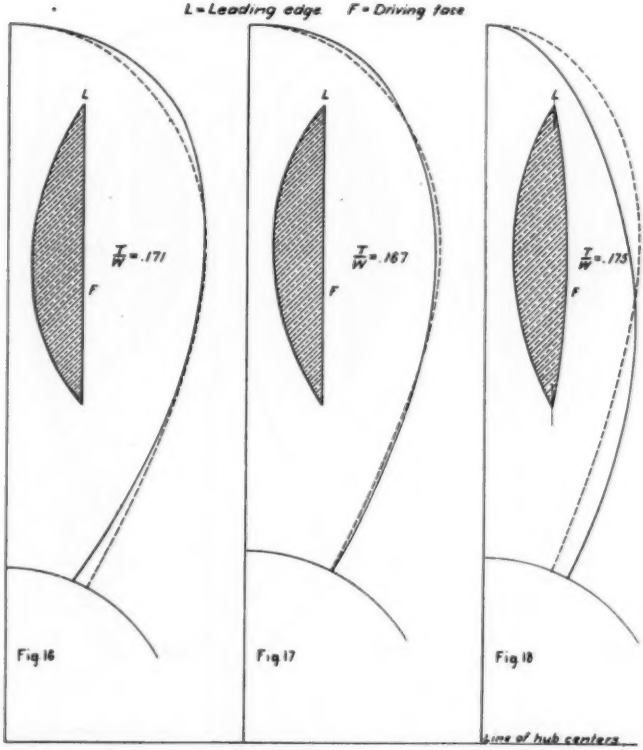
$\frac{P.A}{H.A}$ = .853 $\frac{P}{D}$ = 1.028

Fig 15

Minnesota
Louisiana
New Hampshire

$\frac{P.A}{H.A}$ = .846 $\frac{P}{D}$ = 1.043

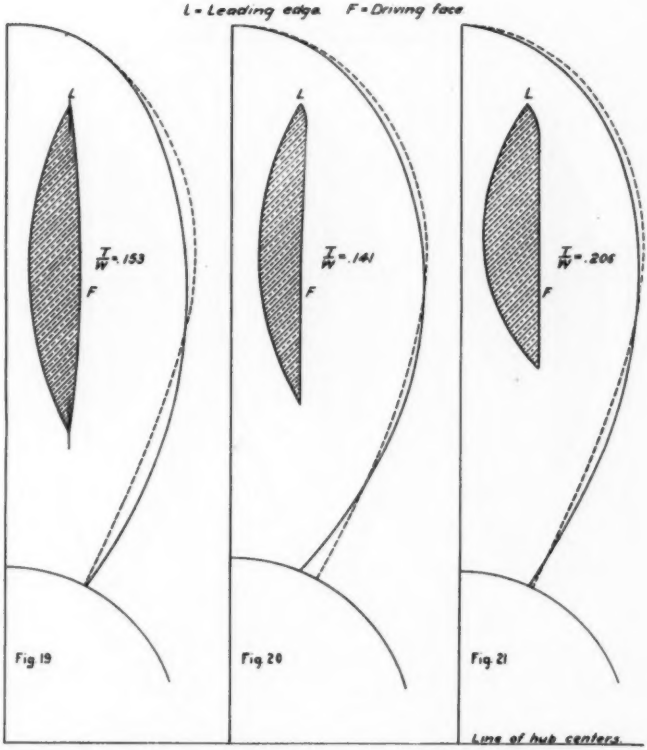
Very good results.



South Carolina
$\frac{P.A}{H.A}$ = .822 $\frac{P}{D}$ = 1.152

Nearsarge.
Kentucky
Illinois.
$\frac{P.A}{H.A}$ = .869 $\frac{P}{D}$ = 1.03
Results excellent

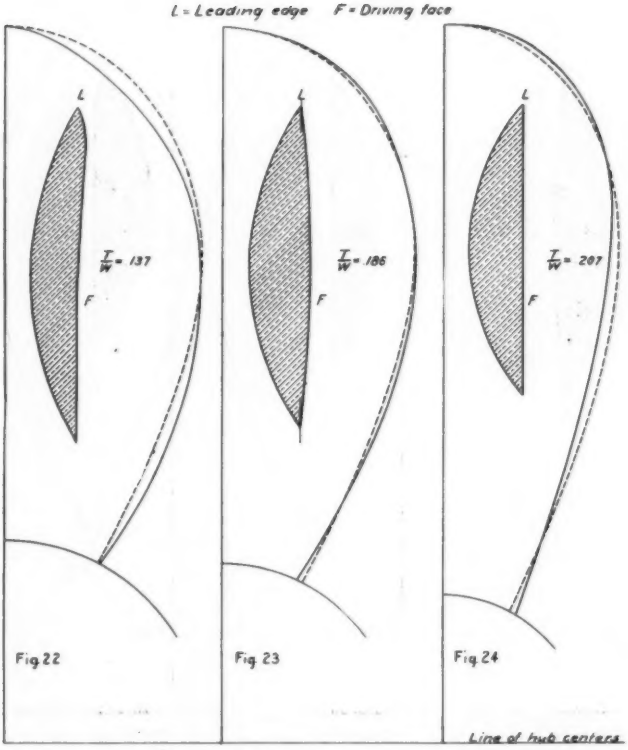
Massachusetts.
Indiana
$\frac{P.A}{H.A}$ = .840 $\frac{P}{D}$ = 1.03
Blades too small
Slip high at all speeds.



Alabama.
$\frac{P.A}{H.A} = .816$ $\frac{P}{D} = 1.09$
Results good

Wisconsin.
$\frac{P.A}{H.A} = .838$ $\frac{P}{D} = 1.13$
Results not so good as Kearsarge and Alabama.

Mississippi
Idaho.
$\frac{P.A}{H.A} = .848$ $\frac{P}{D} = 1.03$
Results doubtful.



Oregon

$\frac{P.A}{H.A}$ = .840 $\frac{P}{D}$ = 1.033

Results much better than Massachusetts

Maine.

$\frac{P.A}{H.A}$ = .798 $\frac{P}{D}$ = 1.125

Results very good

Missouri

$\frac{P.A}{H.A}$ = .852 $\frac{P}{D}$ = 1.07

Results excellent

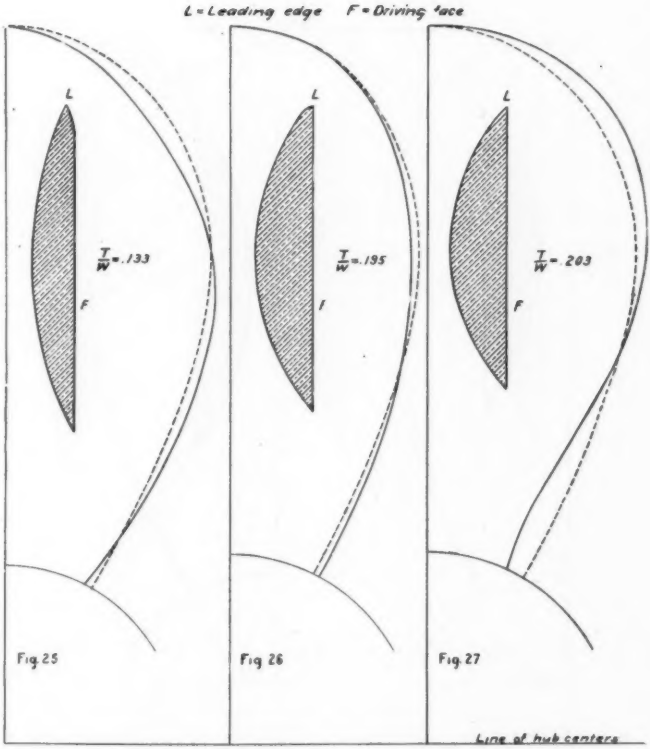


Fig. 25

Ohio

$\frac{P.A}{H.P.}$ = .833 $\frac{P}{D}$ = 1.04

Results good

Fig. 26

Virginia

$\frac{P.A}{H.A}$ = .84 $\frac{P}{D}$ = 1.058

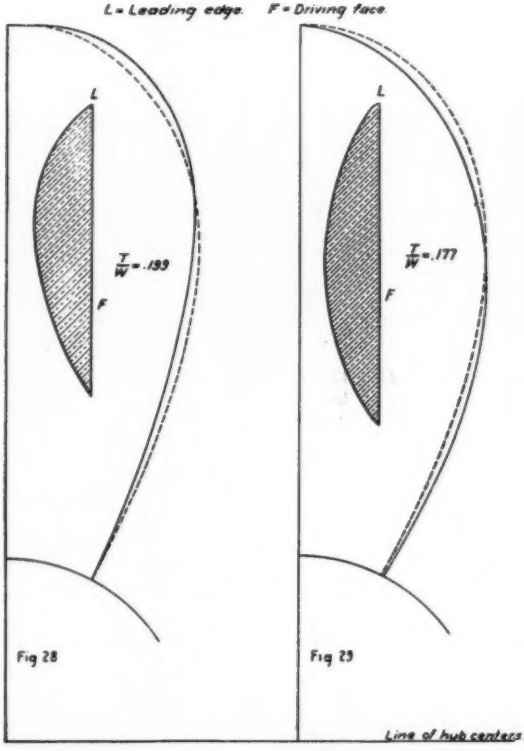
Results about equal to Louisiana

Fig. 27

Rhode Island
New Jersey

$\frac{P.A}{H.A}$ = .831 $\frac{P}{D}$ = 1.06

Results excellent
Not as good at low speeds as Georgia



Georgia

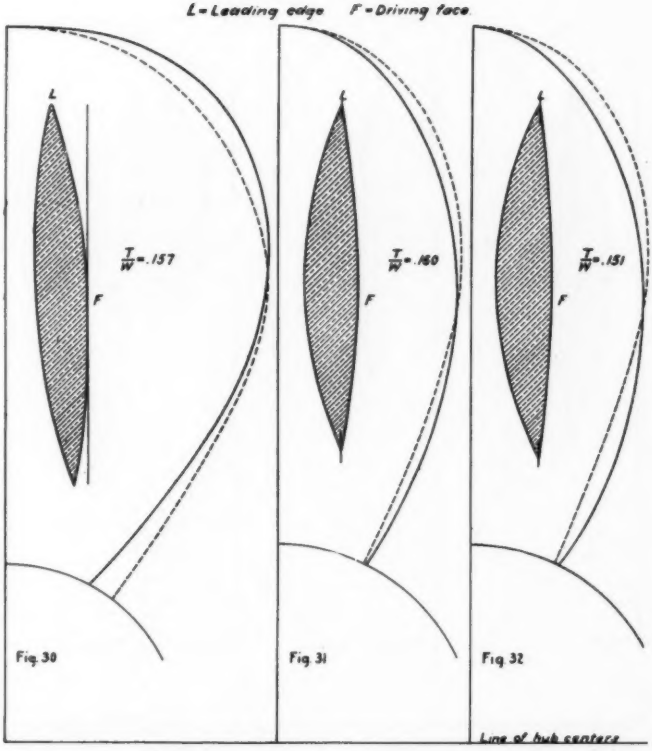
$\frac{P.A}{H.A} = .787$ $\frac{P}{D} = 1.065$

Results excellent

Nebraska

$\frac{P.A}{H.A} = .804$ $\frac{P}{D} = 1.087$

Results doubtful



Wyoming (Cheyenne)[1]

$\frac{P.A}{H.A} = .821$ $\frac{P}{D} = 1.0825$

Results excellent
Propeller too small in diam and pitch too high

Brooklyn

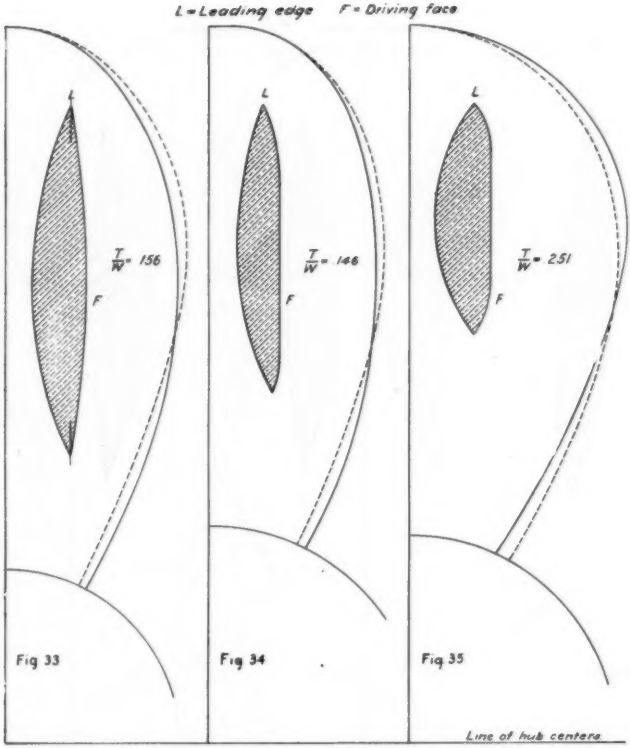
$\frac{P.A}{H.A} = .823$ $\frac{P}{D} = 1.2576$

Results doubtful but good

New York

$\frac{P.A}{H.A} = .819$ $\frac{P}{D} = 1.25$

Not as good as Brooklyn
Slip much increased



Iowa.

$\frac{P.A}{H.A} = .792$ $\frac{P}{D} = 1.18$

Results doubtful but good.

Tacoma.

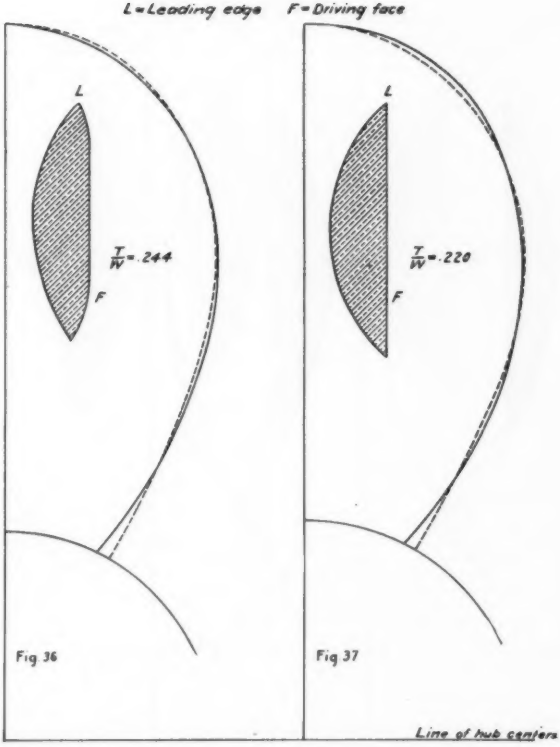
$\frac{P.A}{H.A} = .778$ $\frac{P}{D} = 1.15$

Results poor
Propeller too small diam. too little surface slip very high

Des Moines.
Galveston

$\frac{P.A}{H.A} = .853$ $\frac{P}{D} = 1.119$

Results fair.



Cleveland

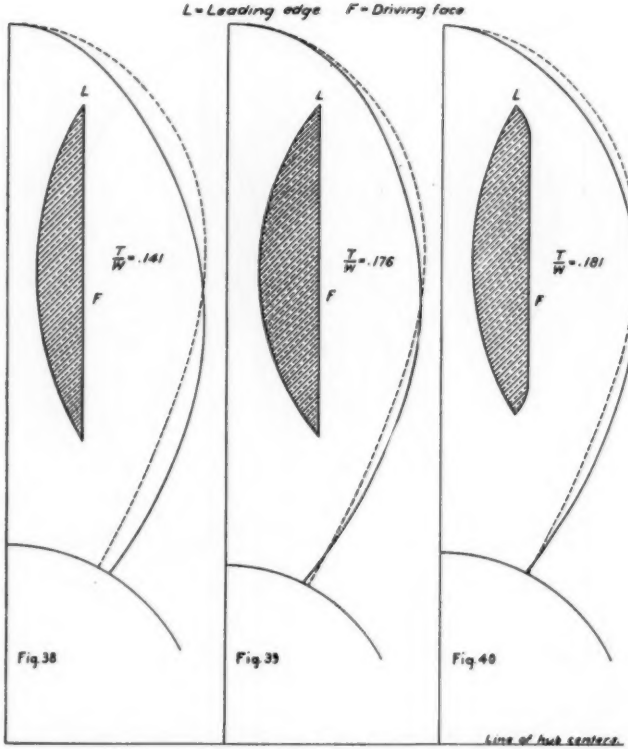
$\frac{P.A}{H.A} = .852$ $\frac{P}{D} = 1.113$

Results excellent
Slip a little high

Chattanooga

$\frac{P.A}{H.A} = .852$ $\frac{P}{D} = 1.0714$

Results very good
second to Cleveland
$\frac{P}{D}$ on trial = 1.113



Olympia

$\frac{P.A}{H.A}$ = .7875 $\frac{P}{D}$ = 1.288

Results doubtful but good

Charleston #1

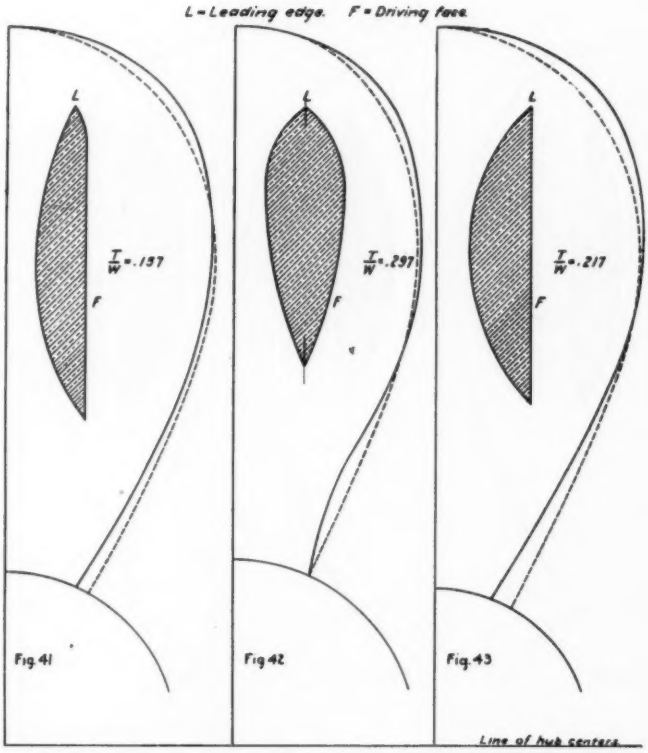
$\frac{P.A}{H.A}$ = .806 $\frac{P}{D}$ = 1.262

Propeller too small
Slip high

Charleston #2

$\frac{P.A}{H.A}$ = .810 $\frac{P}{D}$ = 1.1143

Results better than #1
Slip still high
$\frac{P}{D}$ on trial = 1.171



Milwaukee

$\frac{P.A}{H.A} = .805$ $\frac{P}{D} = 1.1323$

Results excellent

St Louis

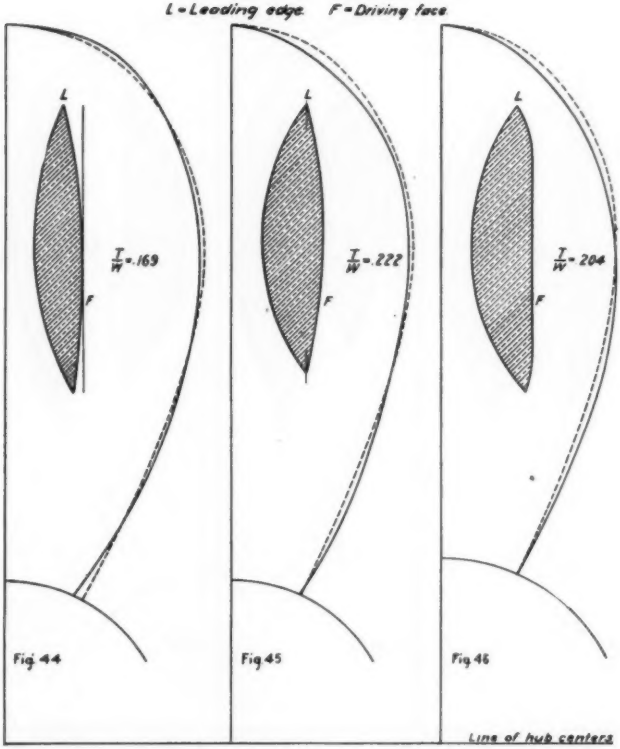
$\frac{P.A}{H.A} = .839$ $\frac{P}{D} = 1.086$

Results very good
Blades believed to have sprung at high powers making actual slips lower than nominal slips.

Birmingham

$\frac{P.A}{H.A} = .801$ $\frac{P}{D} = 1.22$

Results good,
Slip slightly high, too high pitch, too little surface. Diam small for ind thrust



California.
South Dakota
$\frac{P.A}{H.A} = .828$ $\frac{P}{D} = 1.195$
Results doubtful but good

Pennsylvania
Colorado
$\frac{P.A}{H.A} = .804$ $\frac{P}{D} = 1.22$
Results very good
Slip slightly high.

West Virginia.
$\frac{P.A}{H.A} = .807$ $\frac{P}{D} = 1.257$
Results good

L = Leading edge. F = Driving face.

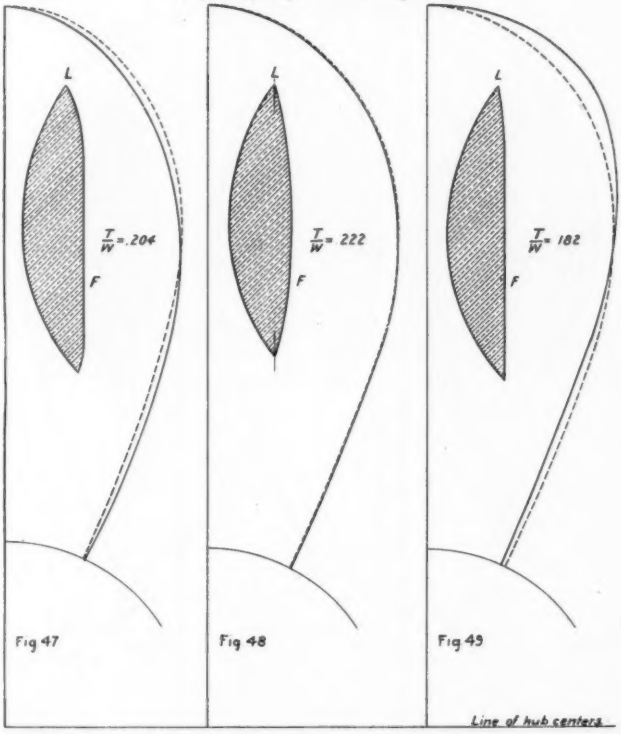


Fig 47

Maryland.

$\frac{P}{H}\frac{A}{A}$ = .789 $\frac{P}{D}$ = 1.286

Same propeller as West Virginia, set at higher pitch, efficiency not so good.

Fig 48

Tennessee.

$\frac{P}{H}\frac{A}{A}$ = .804 $\frac{P}{D}$ = 1.22

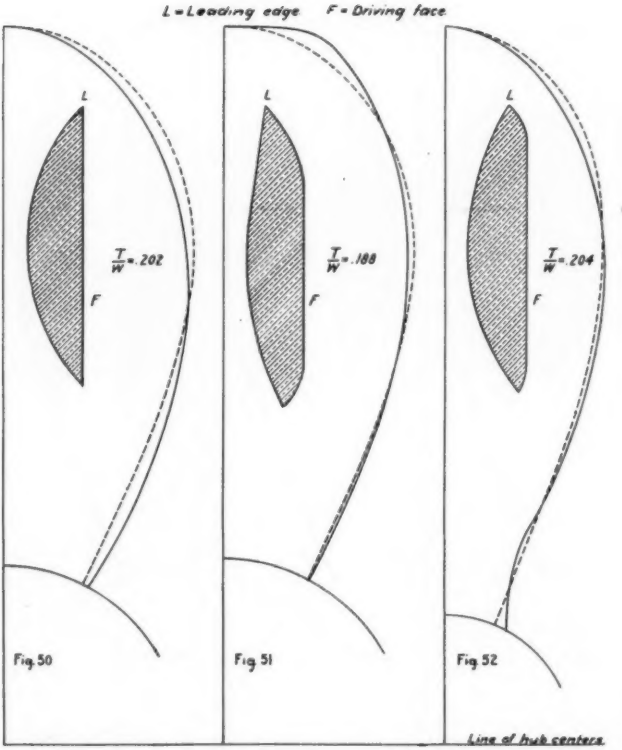
Results very good Slip slightly high.

Fig 49

Montana #2

$\frac{P}{H}\frac{A}{A}$ = 809 $\frac{P}{D}$ = 1.216

Reported smoother running than #1 no record of results.



North Carolina

$\frac{P.A}{H.A} = .780$ $\frac{P}{D} = 1.25$

Results fair.

Montana "I

Set at lower pitch $\frac{P}{D} = 1.208$

Results good.

Washington

$\frac{P.A}{H.A} = .818$ $\frac{P}{D} = 1.208$

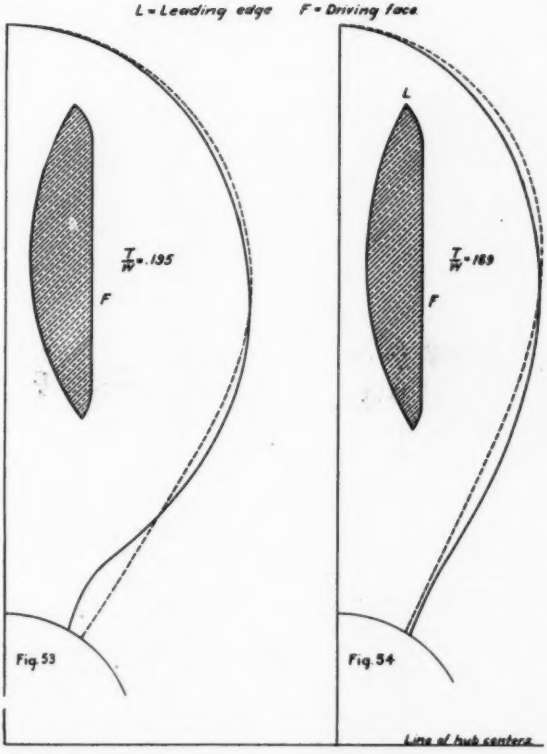
Results best for class.

Perry.

$\frac{P.A}{H.A} = .707$ $\frac{P}{D} = 1.46$

Propeller too small

Vibration high at high speed. Results excellent at low speed



Paul Jones.

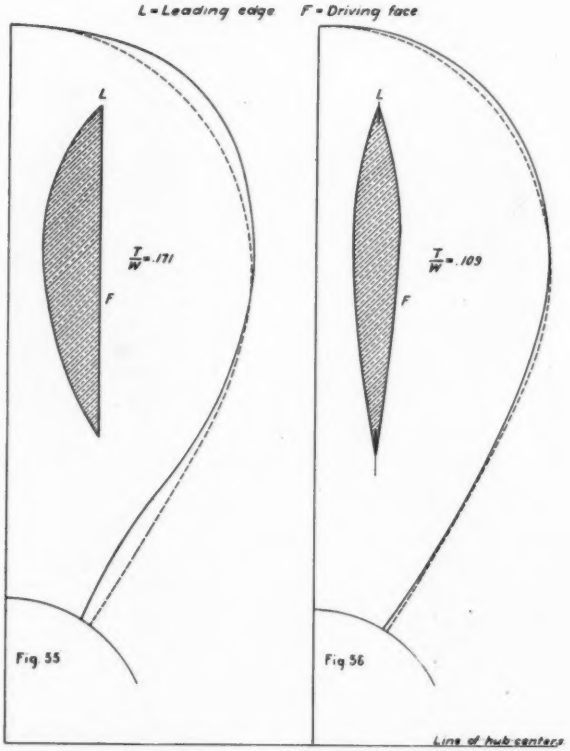
$\frac{P.A}{H.A}$ = .775 $\frac{P}{D}$ = 1.44.

Results very good
Vibration almost nil.

Preble.

$\frac{P.A}{H.A}$ = .760 $\frac{P}{D}$ = 1.4

Results good.
More vibration than
Paul Jones.



Lawrence

$\frac{P A}{H A} = .800$ $\frac{P}{D} = 1.295$

Results fair

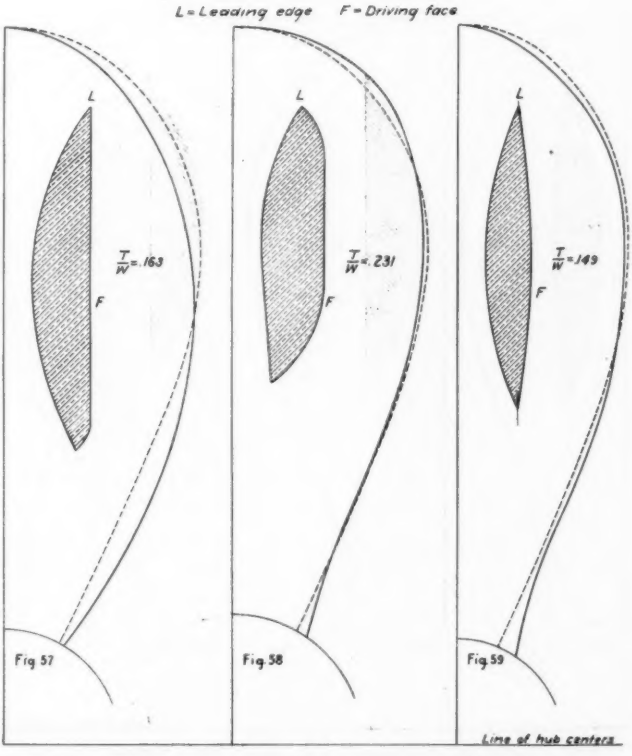
Slip too low

Bainbridge

$\frac{P A}{H A} = .803$ $\frac{P}{D} = 1.325$

Results fair

Pitch too high, slip high



Truxtun

$\frac{P.A.}{H.A.}$ = .755 $\frac{P}{D}$ = 1.408

Results very good

Thornton.

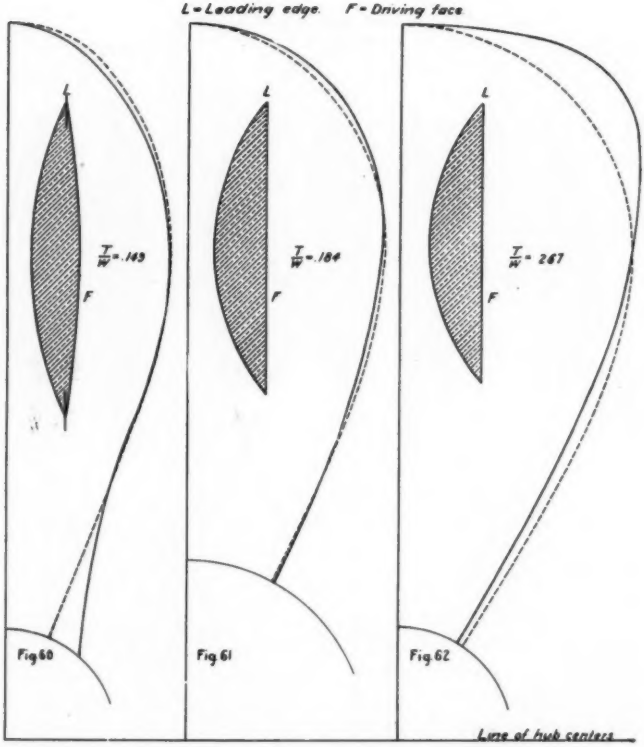
$\frac{P.A.}{H.A.}$ = .737 $\frac{P}{D}$ = 1.59

Results doubtful but good

Barney.
Bagley.
Biddle.

$\frac{P.A.}{H.A.}$ = .68 $\frac{P}{D}$ = 1.62

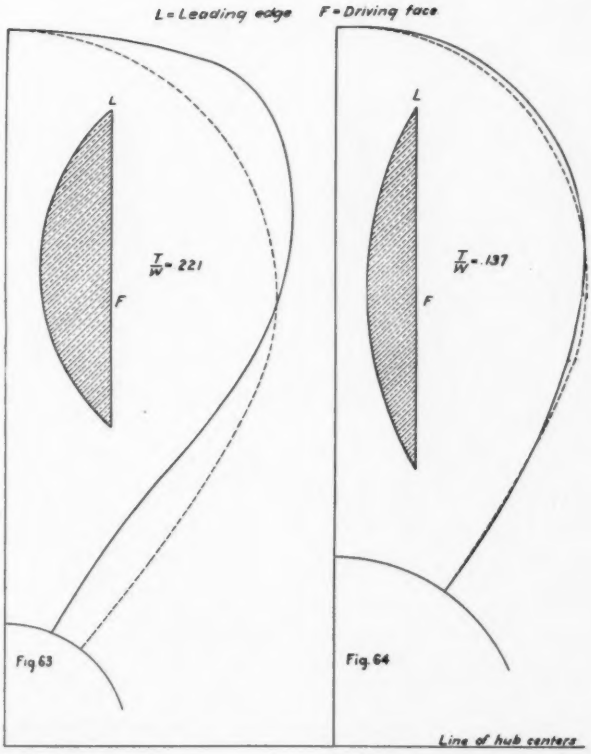
Results very good



Craven
Dahlgren
$\frac{P.A}{H.A}$ = .661 $\frac{P}{D}$ = 1.8
Results excellent

Mississippi #2
$\frac{P.A}{H.A}$ = .840 $\frac{P}{D}$ = 1.047
First reports excellent

Santa Barbara
50 Ft. Launch
$\frac{P.A}{H.A}$ = .801 $\frac{P}{D}$ = 1.122
Results excellent



*691 – 50 Ft Launch

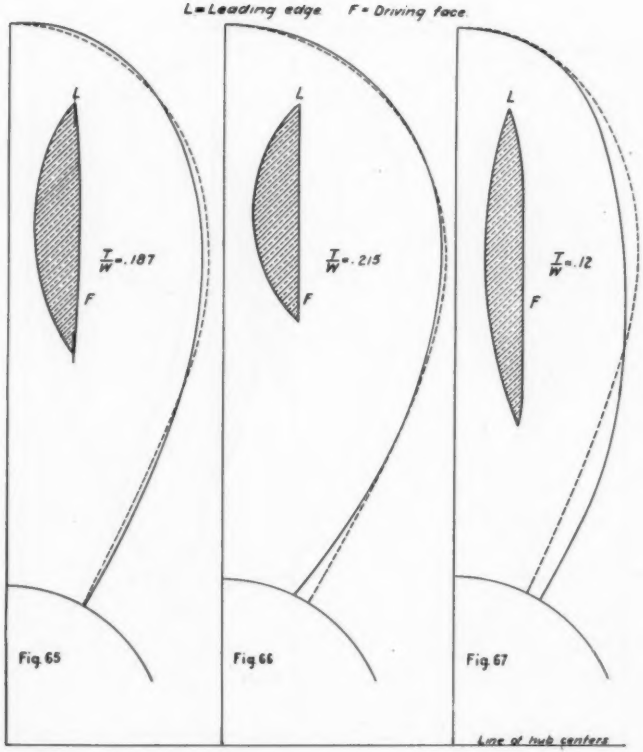
$\frac{P A}{H A}$ = .707 $\frac{P}{D}$ = 1.67

Results excellent

Florida (Tallahassee)

$\frac{P A}{H A}$ = .865 $\frac{P}{D}$ = .912

Set at .9797 = $\frac{P}{D}$ for trial.



Nevada.

$\frac{P.A.}{H.A.} = .875$ $\frac{P}{D} = .76$

Pitch increases radially from 6°9' at hub to 7°3' at tip. Set at .8452 = $\frac{P}{D}$ for trial.

Arkansas.

$\frac{P.A.}{H.A.} = .882$ $\frac{P}{D} = .806$

Set at .806 = $\frac{P}{D}$ for trial.

Castro (Gasolene engine)

$\frac{P.A.}{H.A.} = .84$ $\frac{P}{D} = .967$

Results very good

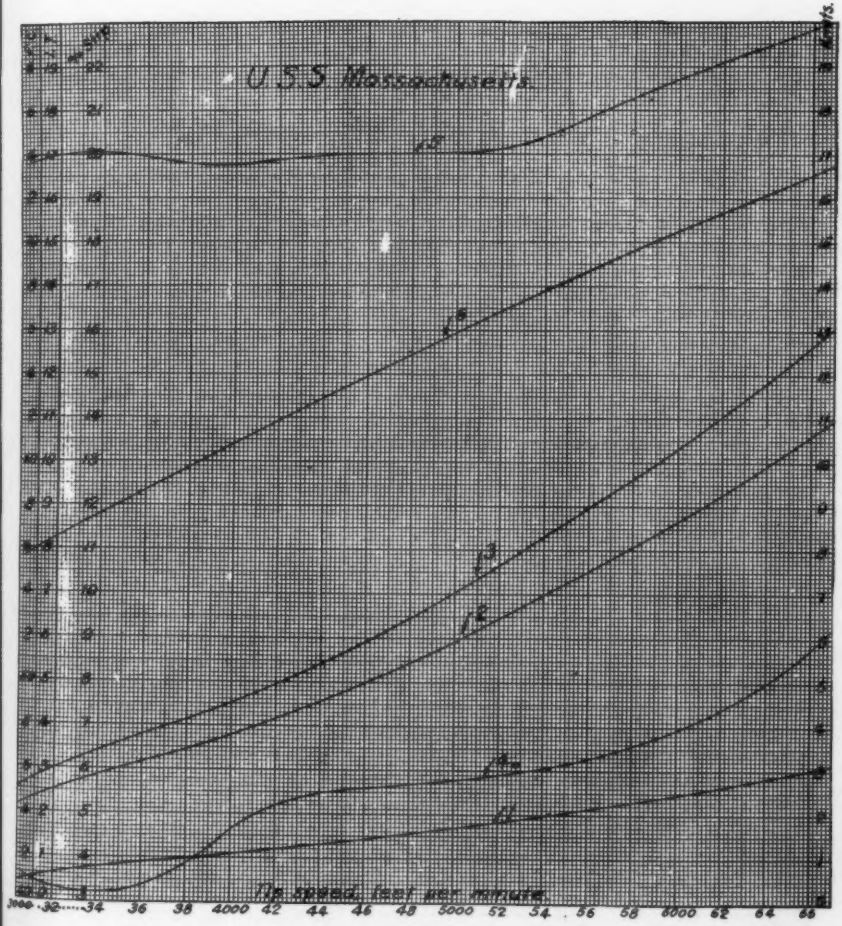

U.S.S. Massachusetts.
Hp.
Revs.
Ip.
Speed, feet per minute.
32
34
36
38
4000
42
44
46
48
5000
52
54
56
58
6000
62
64
66

Plate 1.

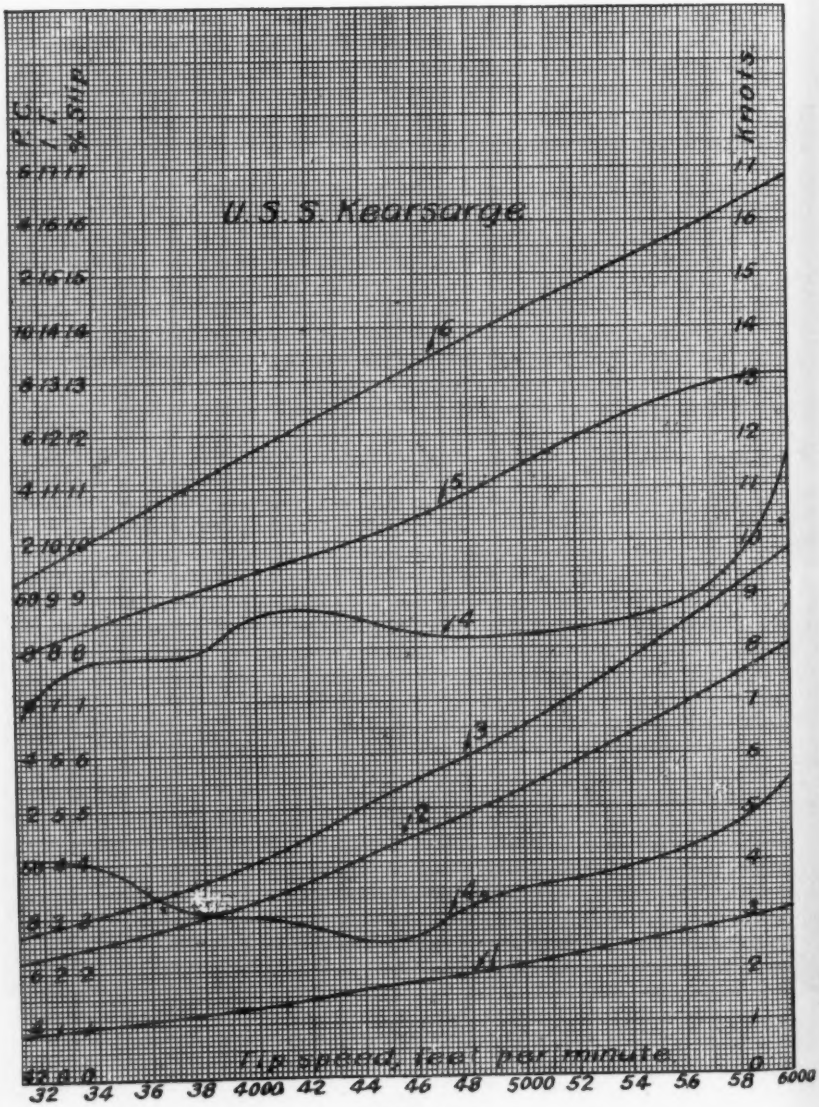

U.S.S. Kearsarge
Knots
H.P. Scale
R.P. Speed, Revs. per minute
32 34 36 38 4000 42 44 46 48 5000 52 54 56 58 6000
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0

Plate 4.

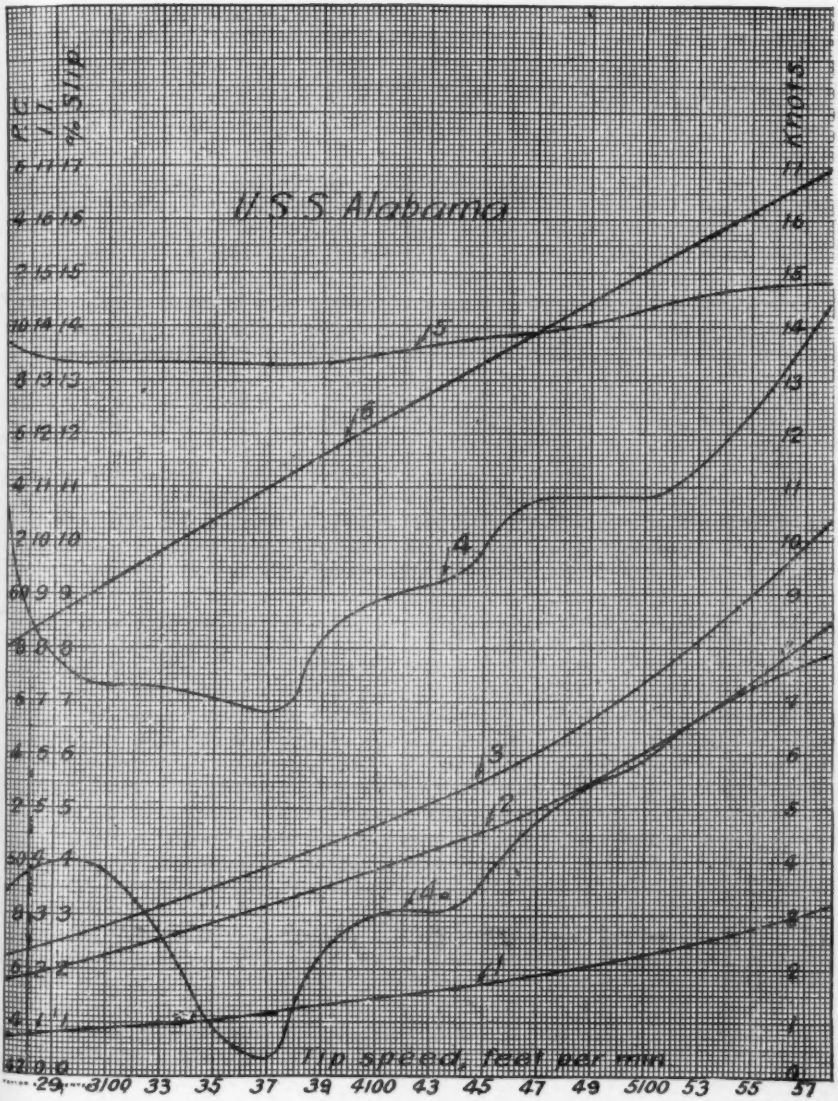

U.S.S. Alabama
Knots
Tip speed, feet per min.
29 3100 33 35 37 39 4100 43 45 47 49 5100 53 55 57

Plate 6.

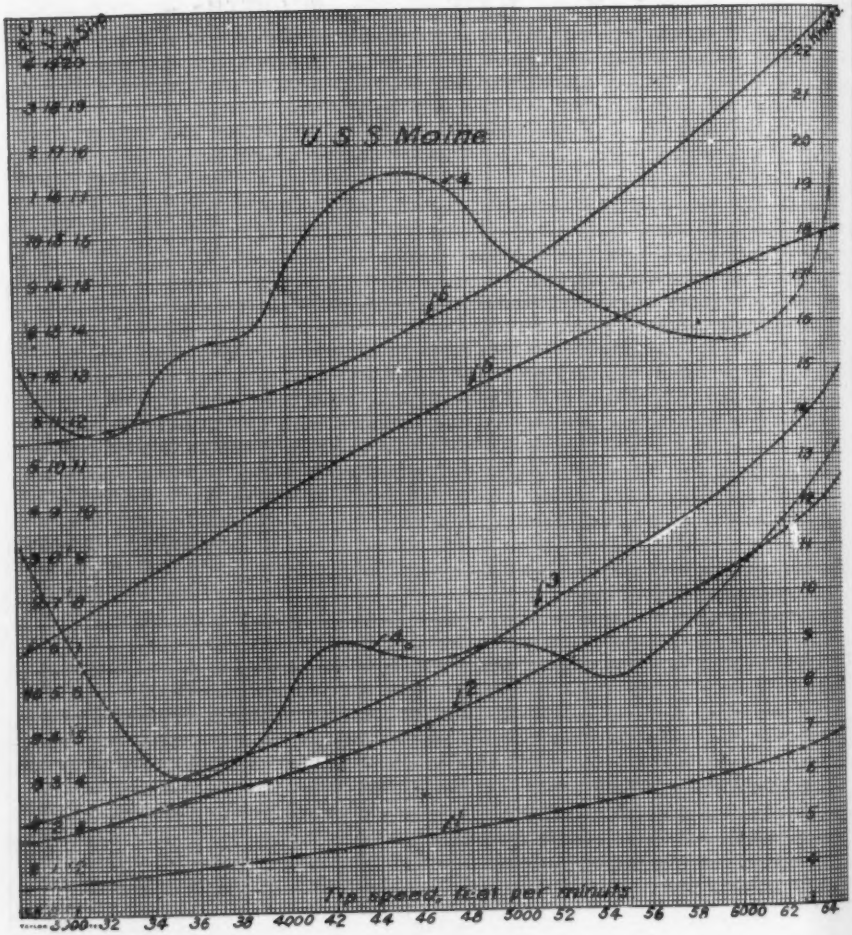


Plate 8.

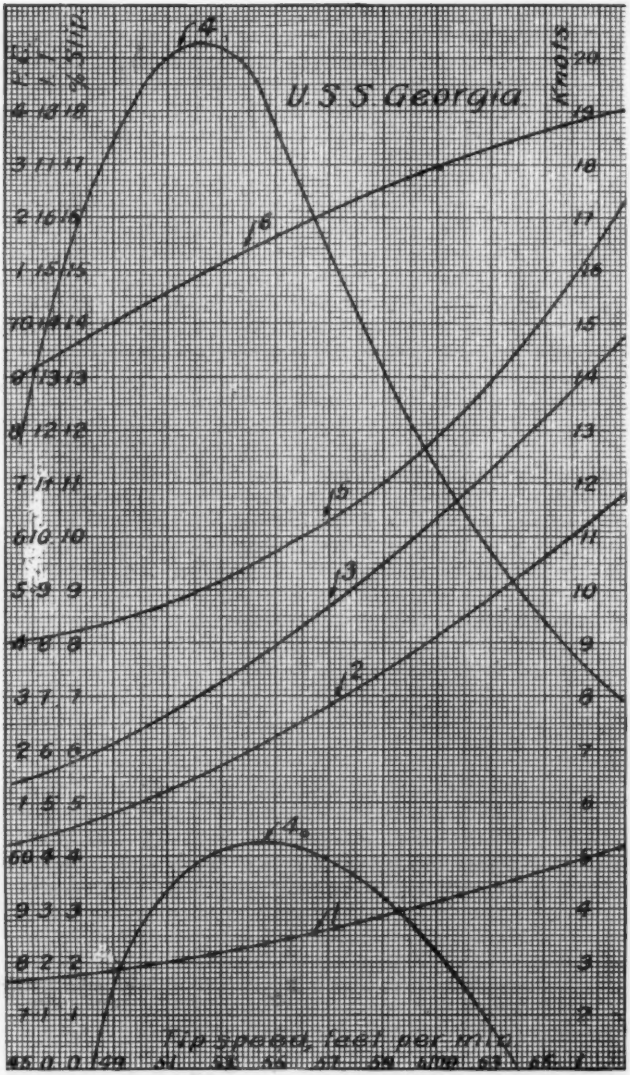


Plate 11.

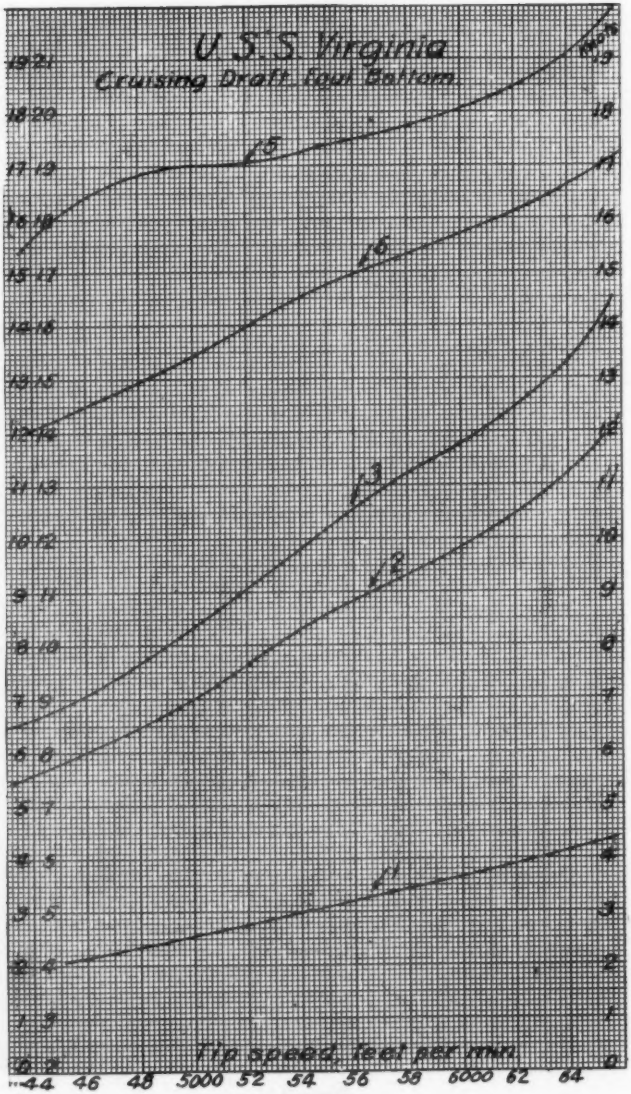

U.S.S. Virginia
Cruising Draft. Foul Bottom.
Tip speed, feet per min.
44 46 48 5000 52 54 56 58 6000 62 64

Plate 12.

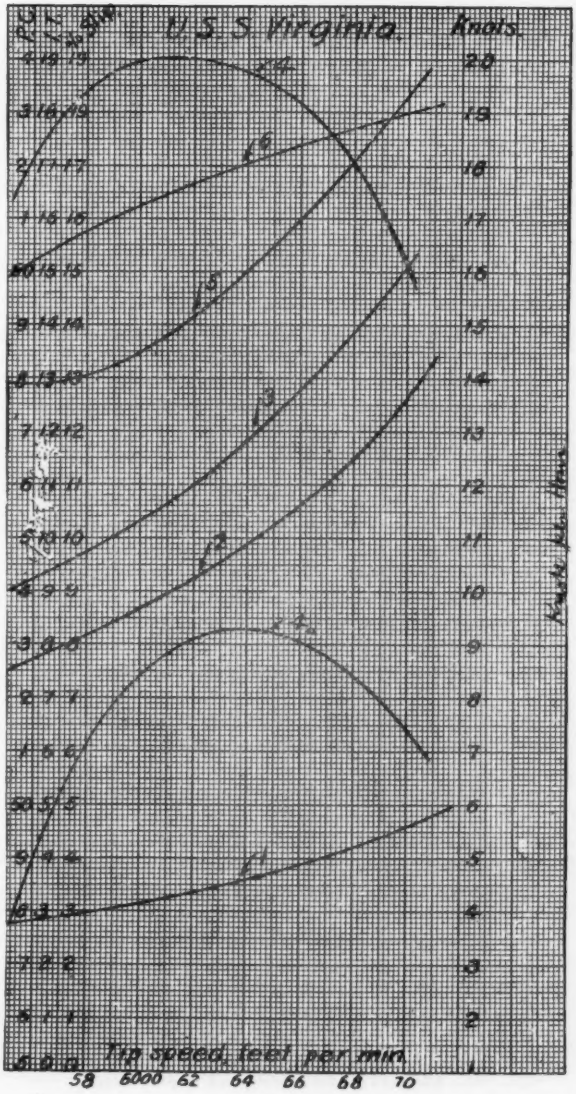

U.S.S. Virginia.
Knots.
Tip speed feet per min.
58
6000
62
64
66
68
70

Plate 12.

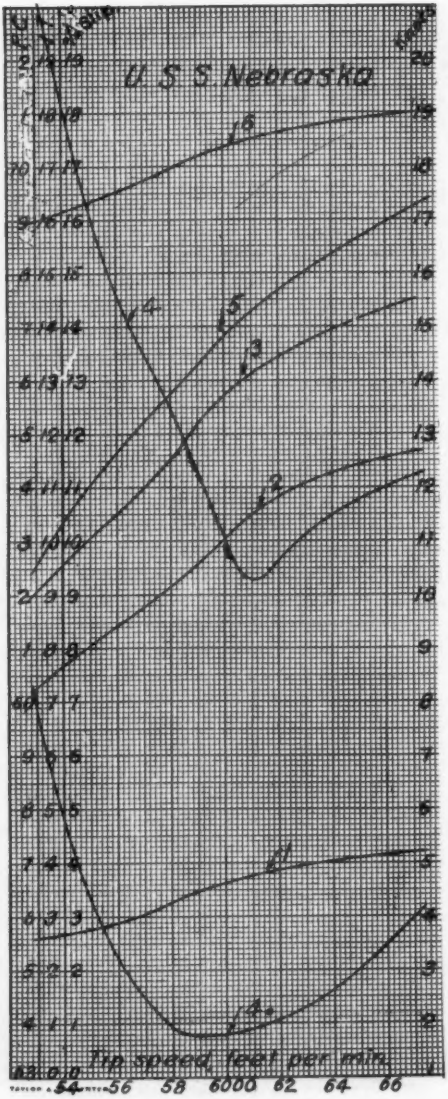


Plate 13.

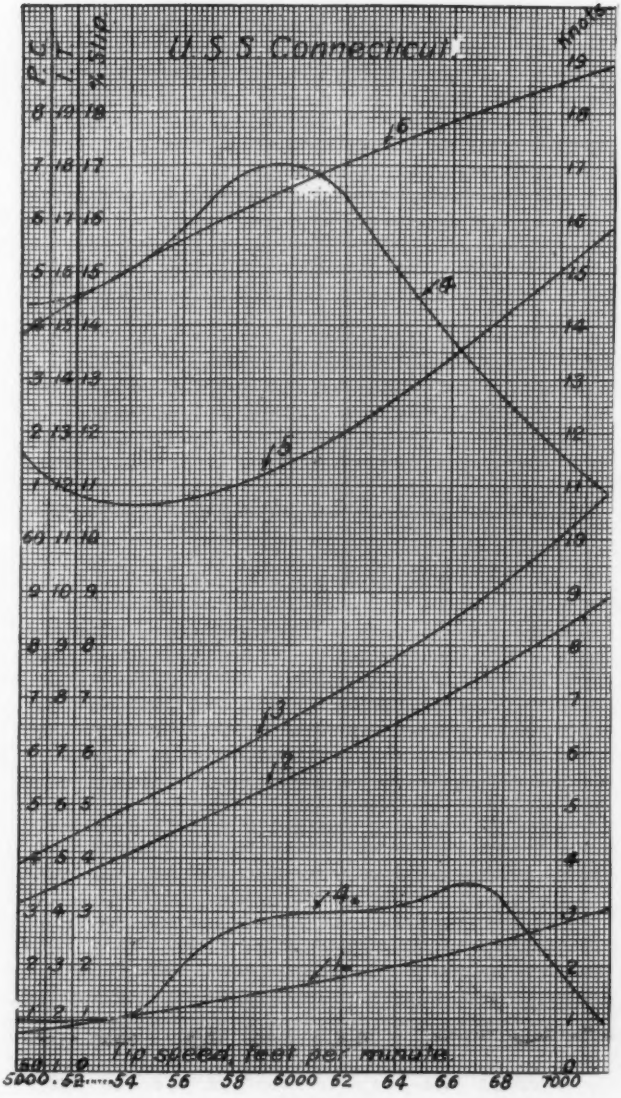

U. S. S. Connecticut.
Knots
Slip %
Tip speed, feet per minute.
5000
52
54
56
58
6000
62
64
66
68
7000

Plate 17.

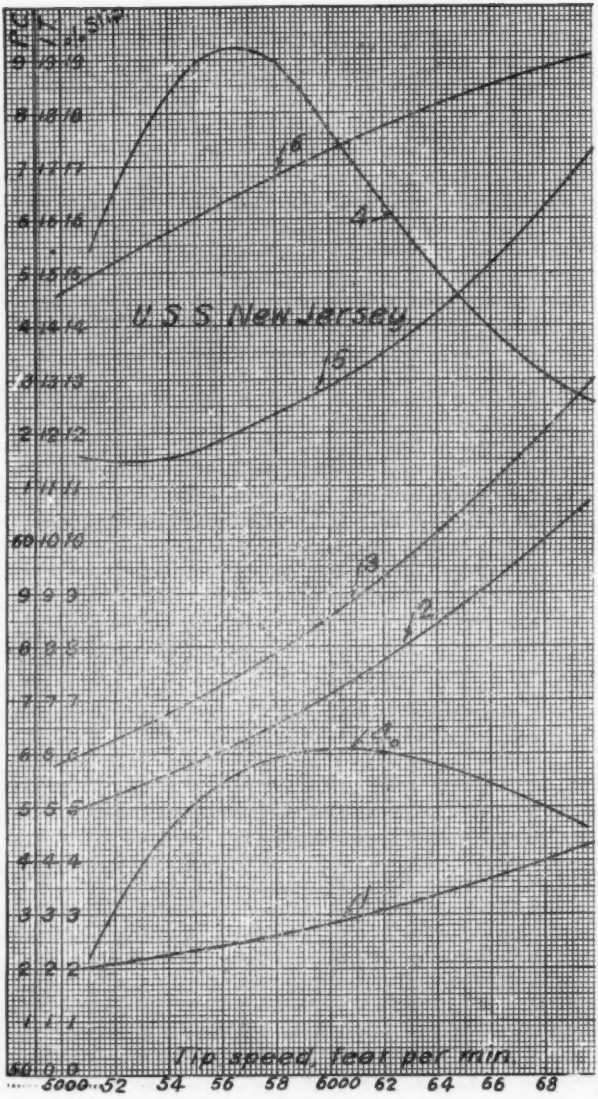

U.S.S. New Jersey
Tip speed, feet per min.
5000 52 54 56 58 6000 62 64 66 68

Plate 15.

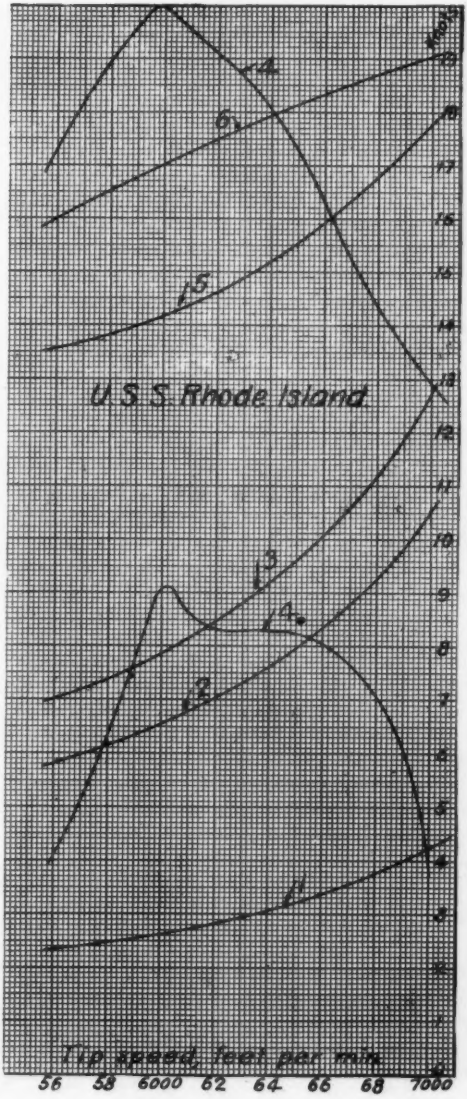

U.S.S. Rhode Island.
Tip speed, feet per min.
56
58
6000
62
64
66
68
7000

Plate 14.

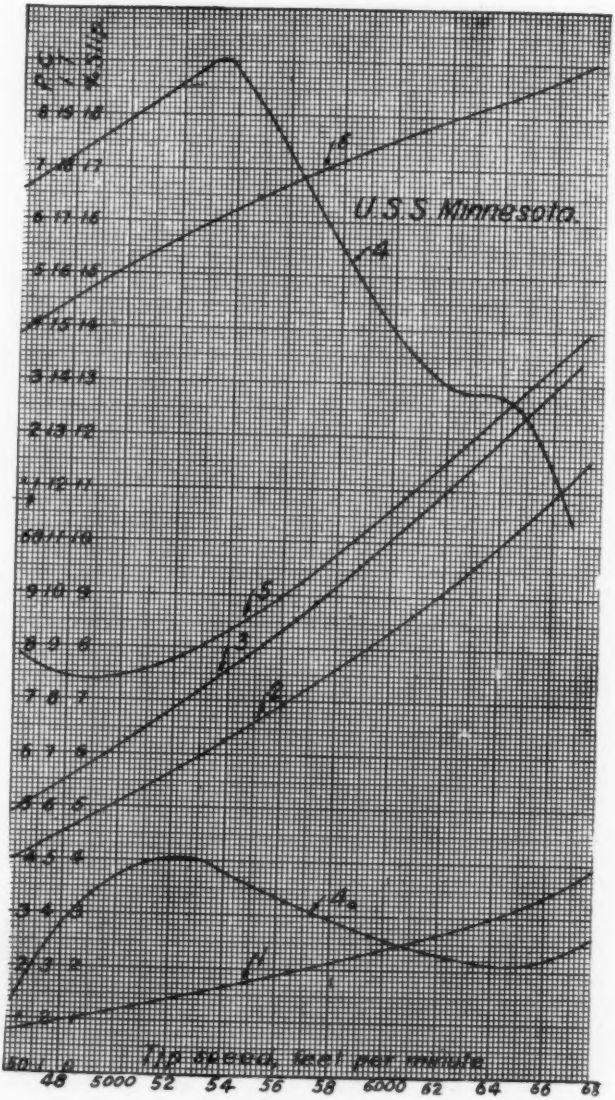

U.S.S. Minnesota.
Tip speed, feet per minute.
48
5000
52
54
56
58
6000
62
64
66
68

Plate 23.

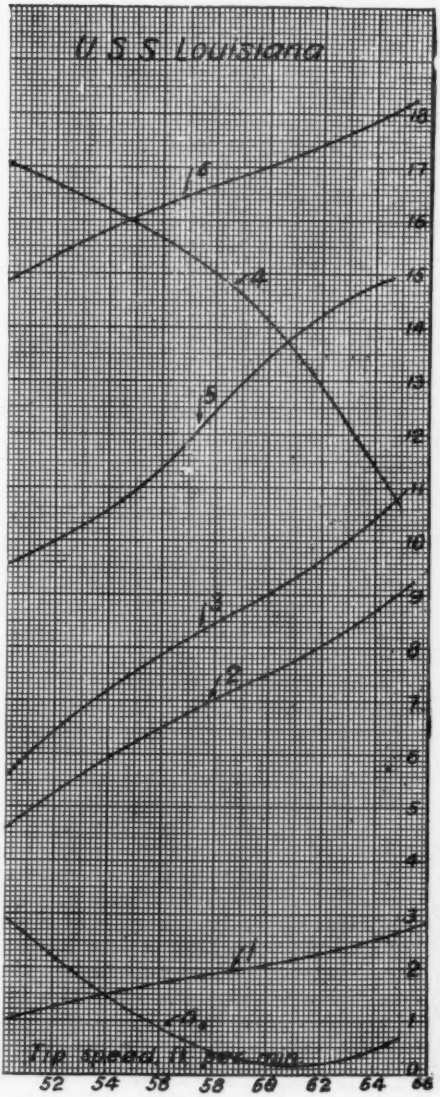


Plate 16.

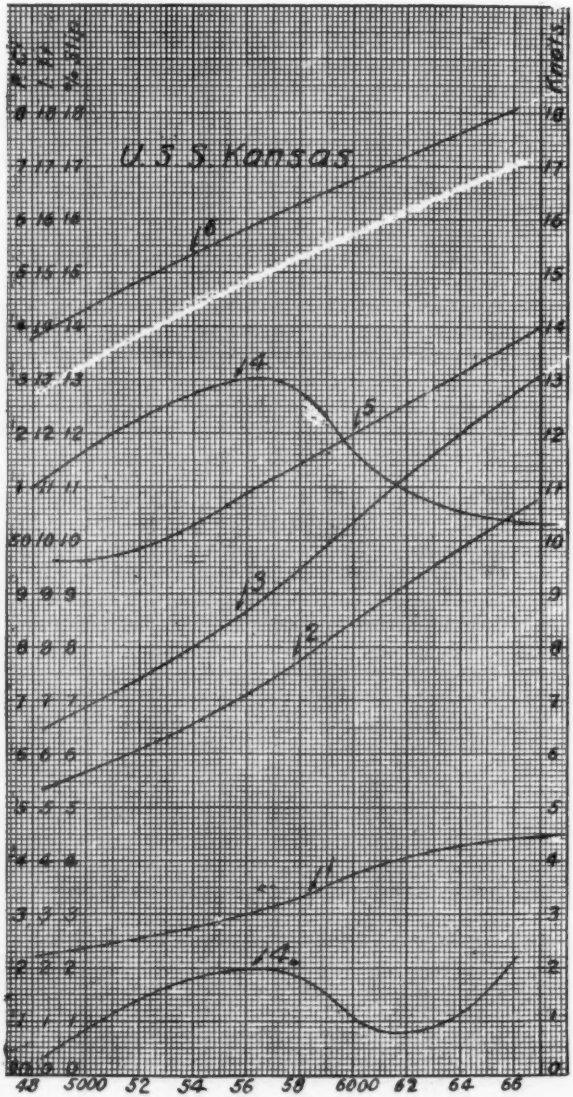

U. S. S. Kansas
16
14
15
13
12
11
Knots.
48
3000
52
54
56
58
6000
62
64
66

Plate 18.

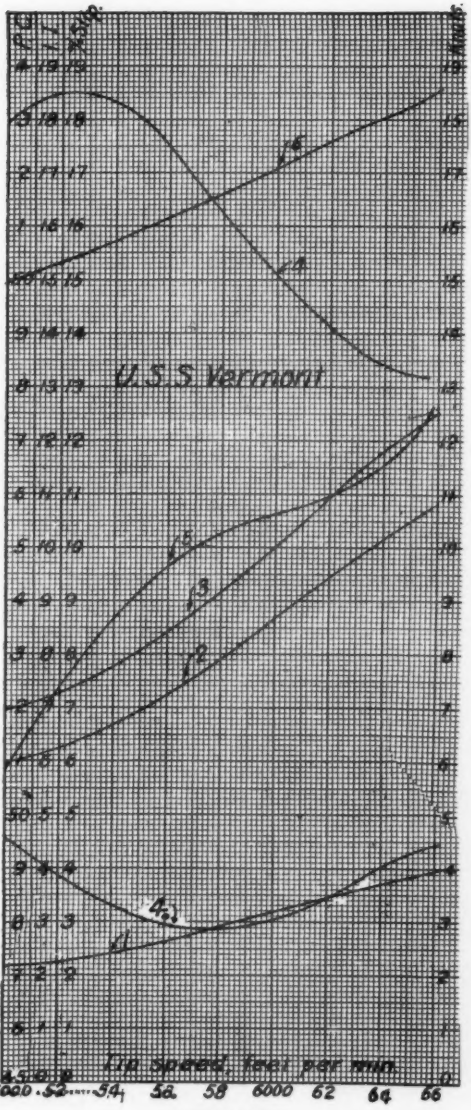

U.S.S. Vermont
Tip Speed, feet per min.
5000
52
54
56
58
6000
62
64
66

Plate 19.

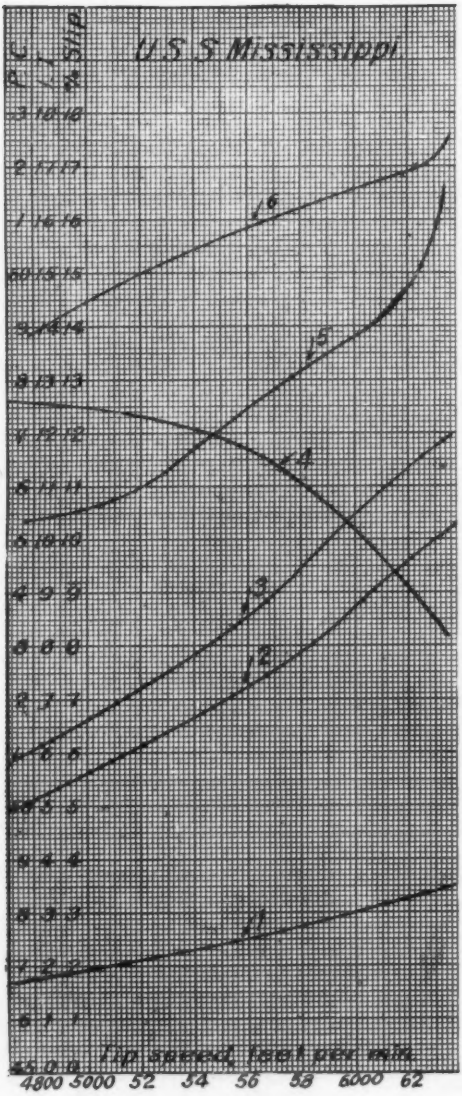

U.S.S. Mississippi.
Slip
Tip speed, feet per min.
4800 5000 52 54 56 58 6000 62

Plate 22.

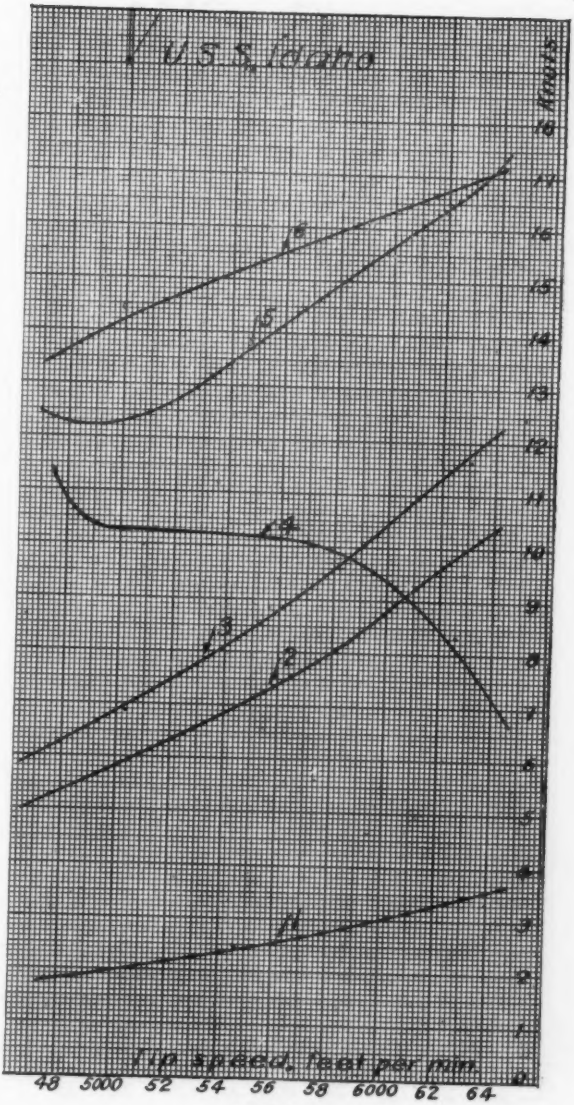

U.S.S. Idaho
Knots
Tip speed, feet per min.
48
5000
52
54
56
58
6000
62
64

Plate 22.

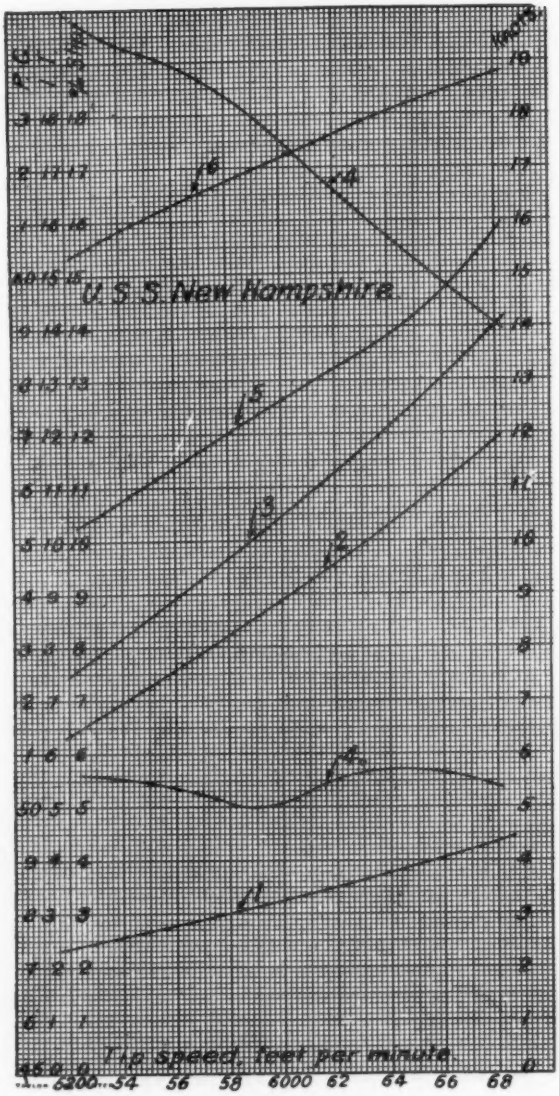

U. S. S. New Hampshire.
Tip speed, feet per minute.
6200
54
56
58
6000
62
64
66
68

Plate 21.

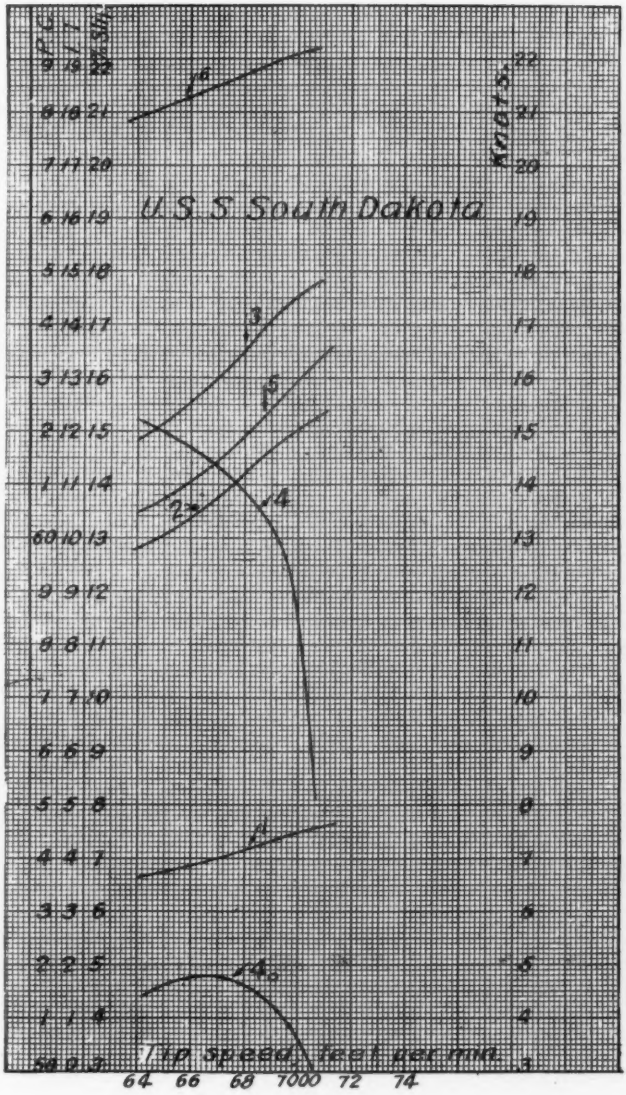

U.S.S. South Dakota
Knots.
Tip speed, feet per min.
64 66 68 7000 72 74

Plate 25.

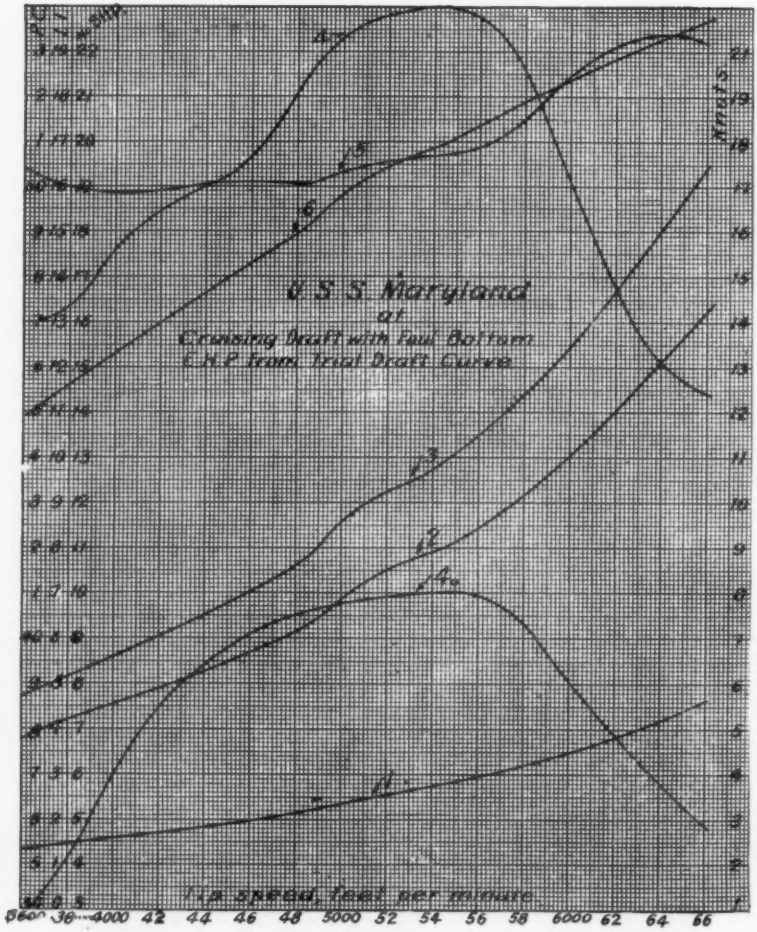

U S S. Maryland
at
Cruising Draft with Foul Bottom
E.H.P. from Trial Draft Curve
Trial Speed, feet per minute
Knots
36 4000 42 44 46 48 5000 52 54 56 58 6000 62 64 66

Plate 26.

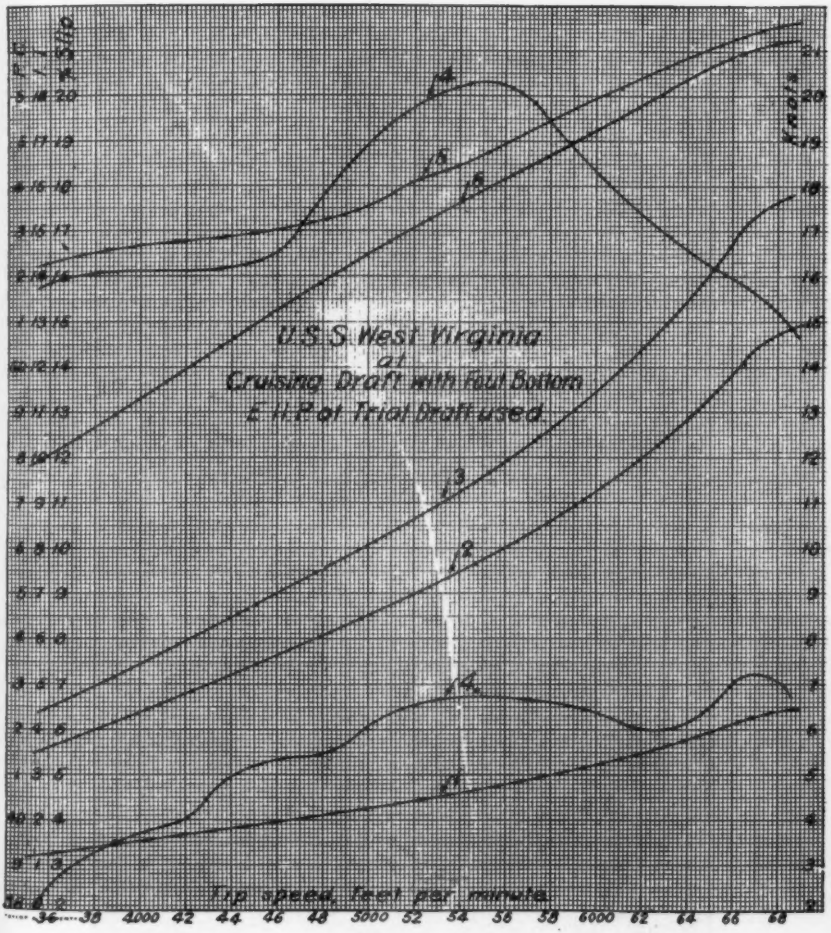

U.S.S. West Virginia
at
Cruising Draft with Foul Bottom
E.H.P. at Trial Draft used.
Trip speed, feet per minute.
36
38
4000
42
44
46
48
5000
52
54
56
58
6000
62
64
66
68

Plate 27.

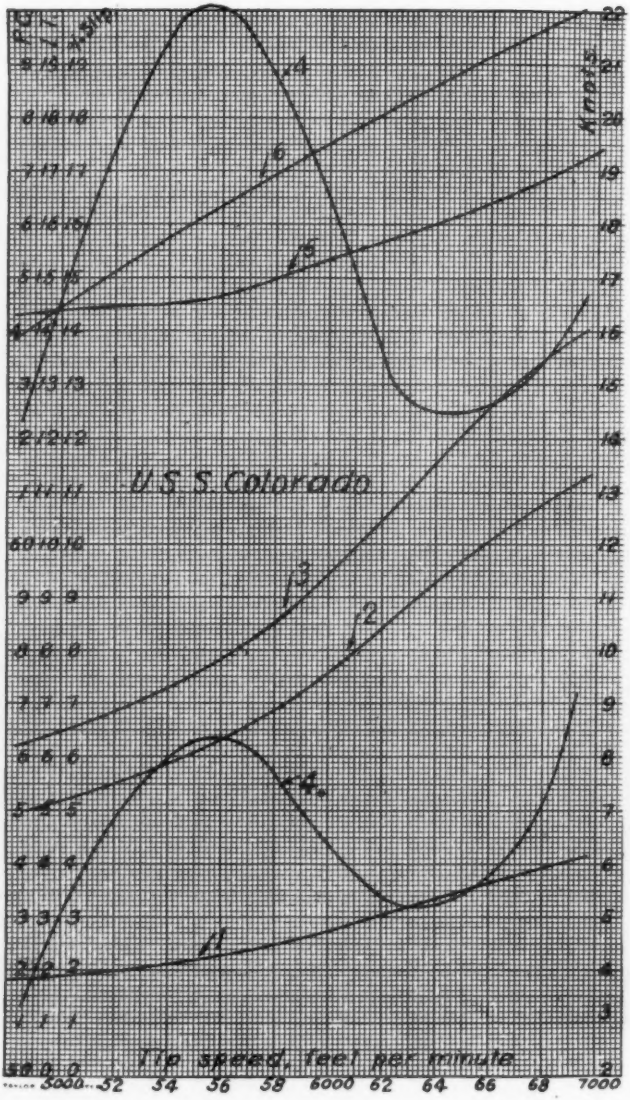

U.S.S. Colorado
Tip speed, feet per minute
5000
52
54
56
58
6000
62
64
66
68
7000
4
6
5
3
2
1

Plate 28.

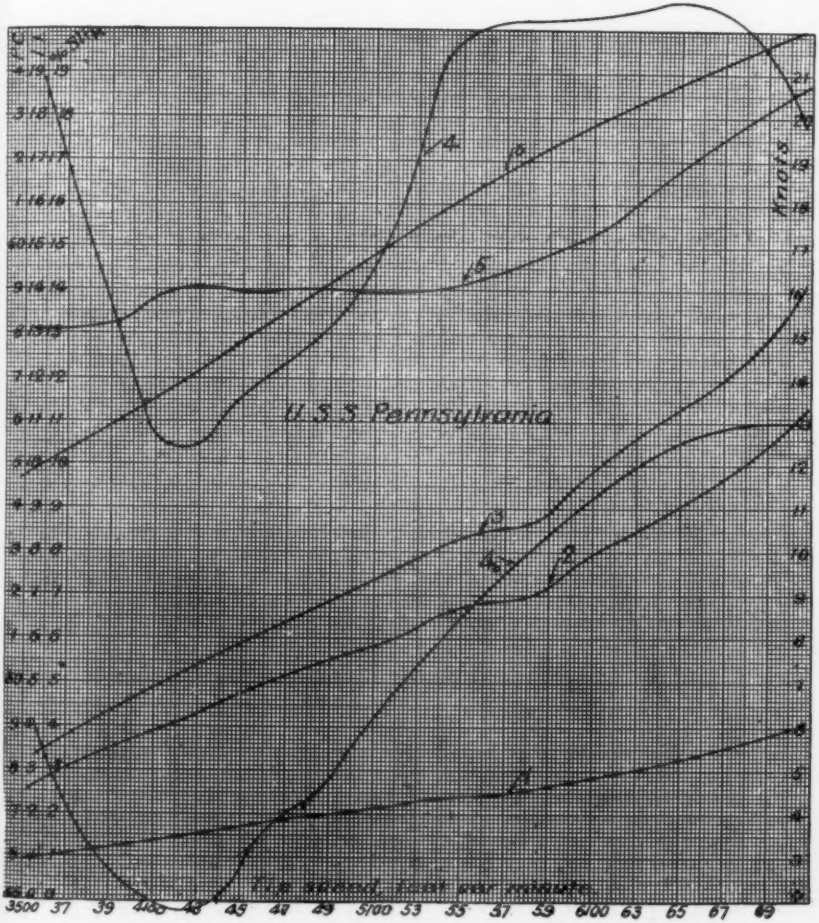


Plate 29.

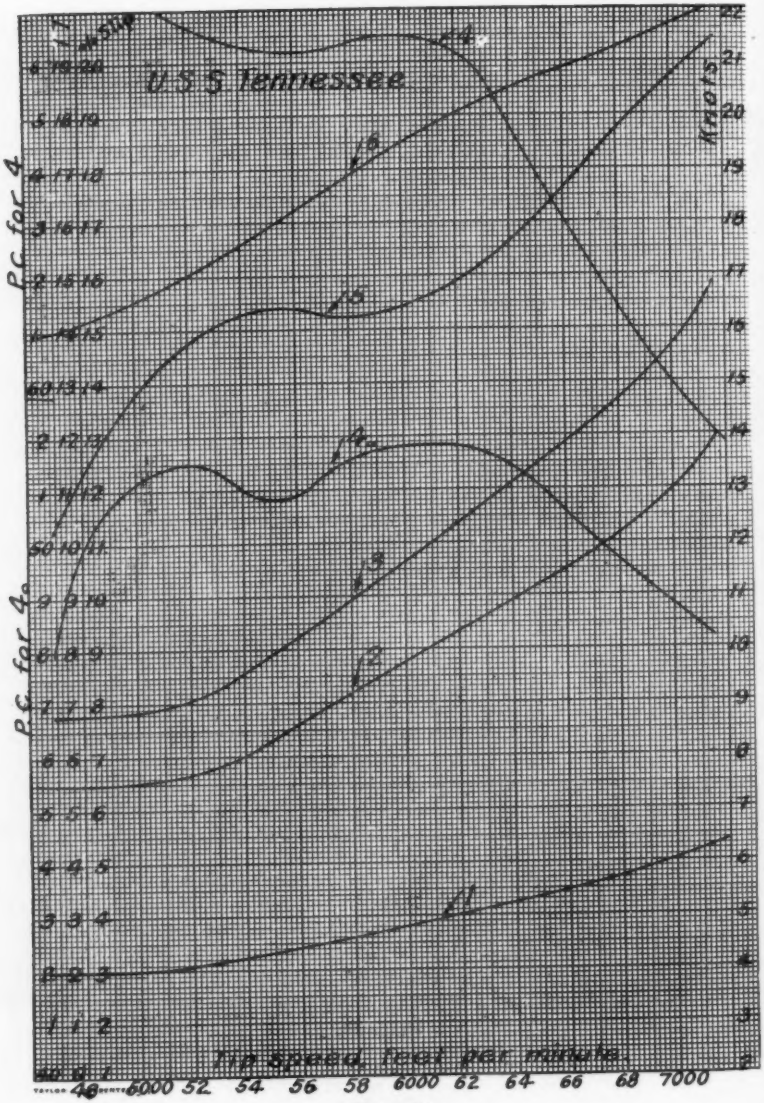

U S S Tennessee
P/C for 4
P/C for 4a
Knots
Tip Speed, feet per minute
6000 52 54 56 58 6000 62 64 66 68 7000

Plate 30.

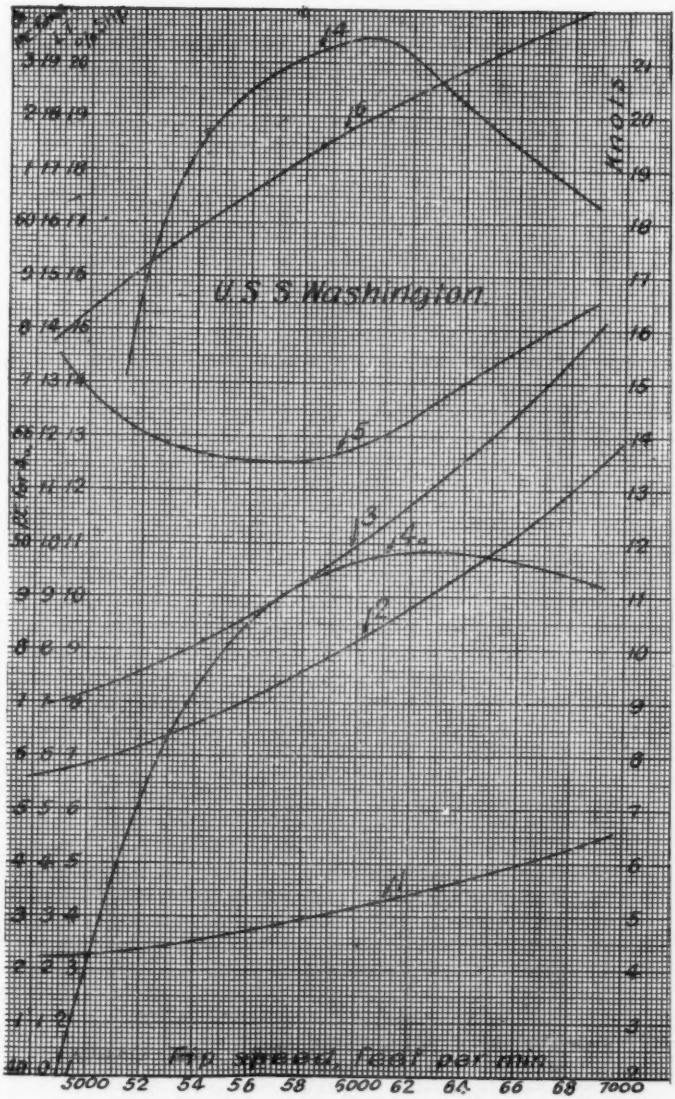

U.S.S. Washington
Knots
Slip %
Trip speed, feet per min.
3000 52 54 56 58 5000 62 64 66 68 7000

Plate 31.

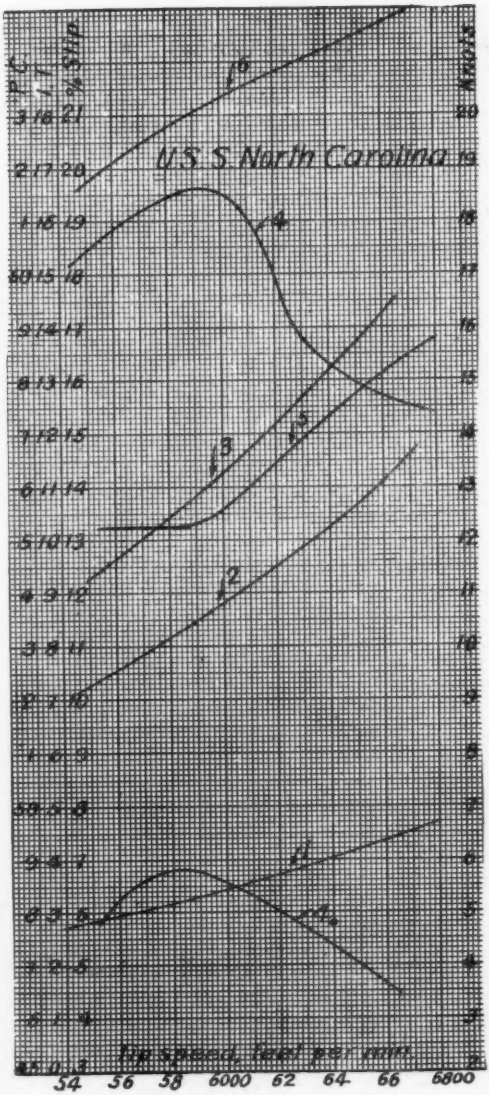

U.S.S. North Carolina
f6
f4
f3
f5
f2
f1
f7
Thr.
Revs.
Hp. speed, feet per min.
54
56
58
6000
62
64
66
6800

Plate 32.

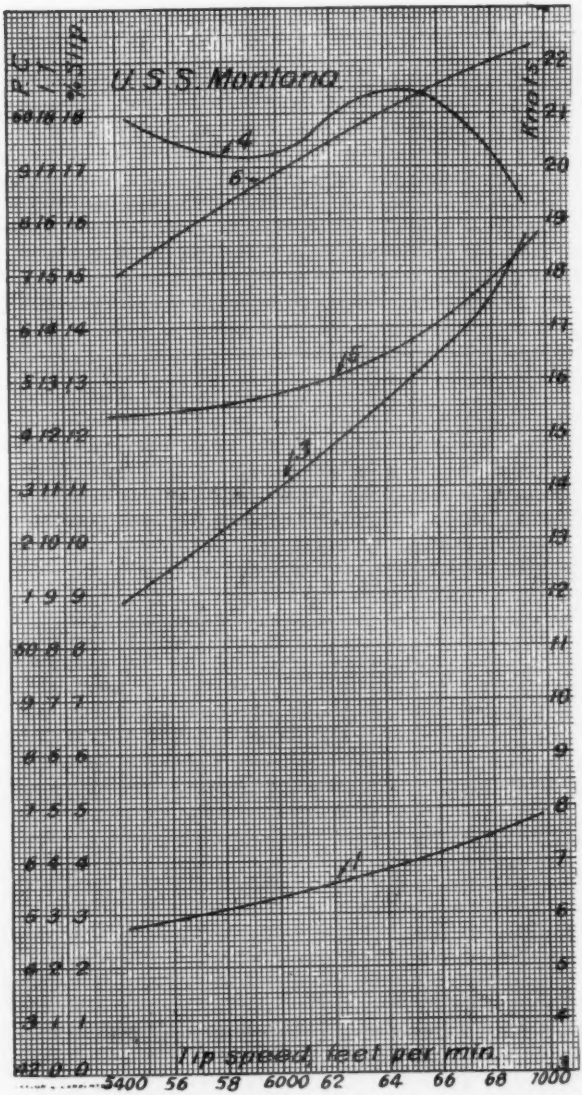
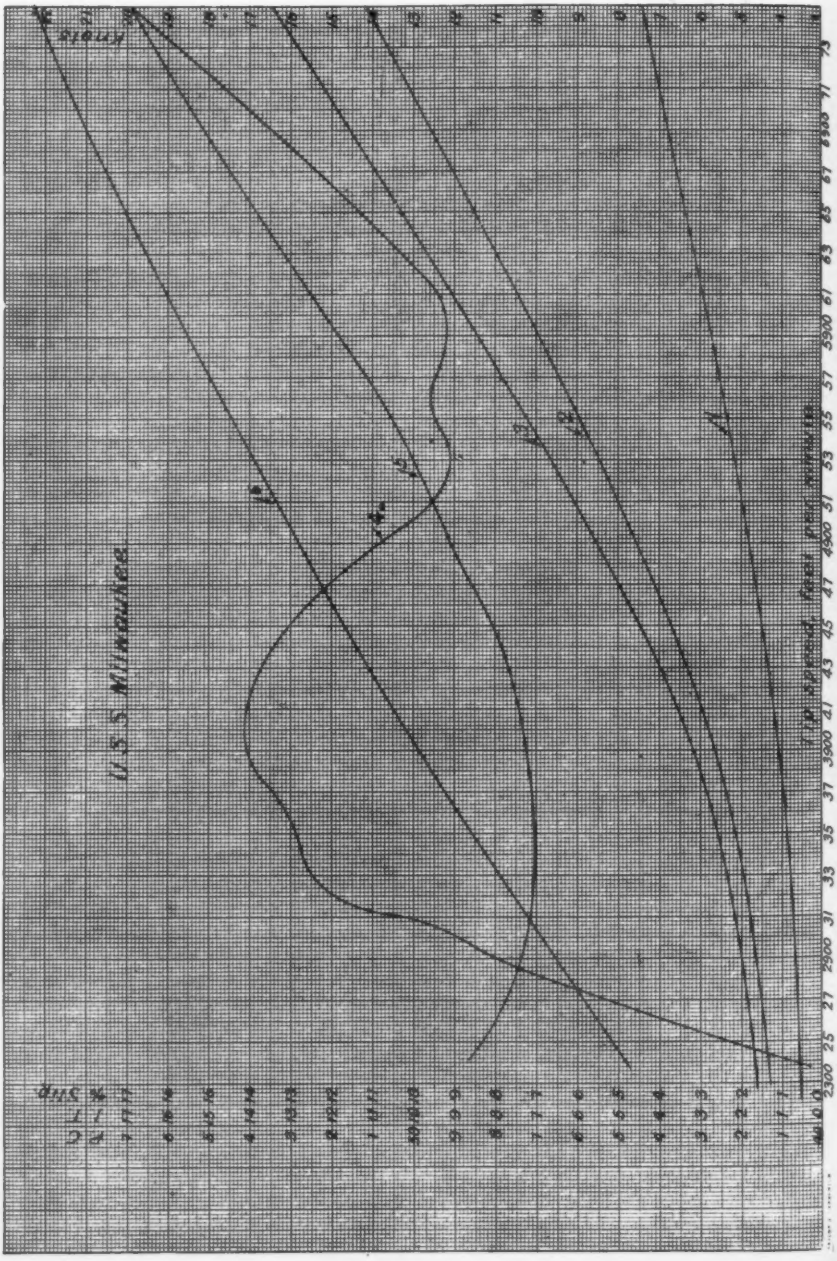

U.S.S. Montana.
Knots
Tip speed, feet per min.
5400
56
58
6000
62
64
66
68
7000

Plate 33.


U.S.S. Milwaukee
I.H.P. Speed, Feet per minute
Plate 35.

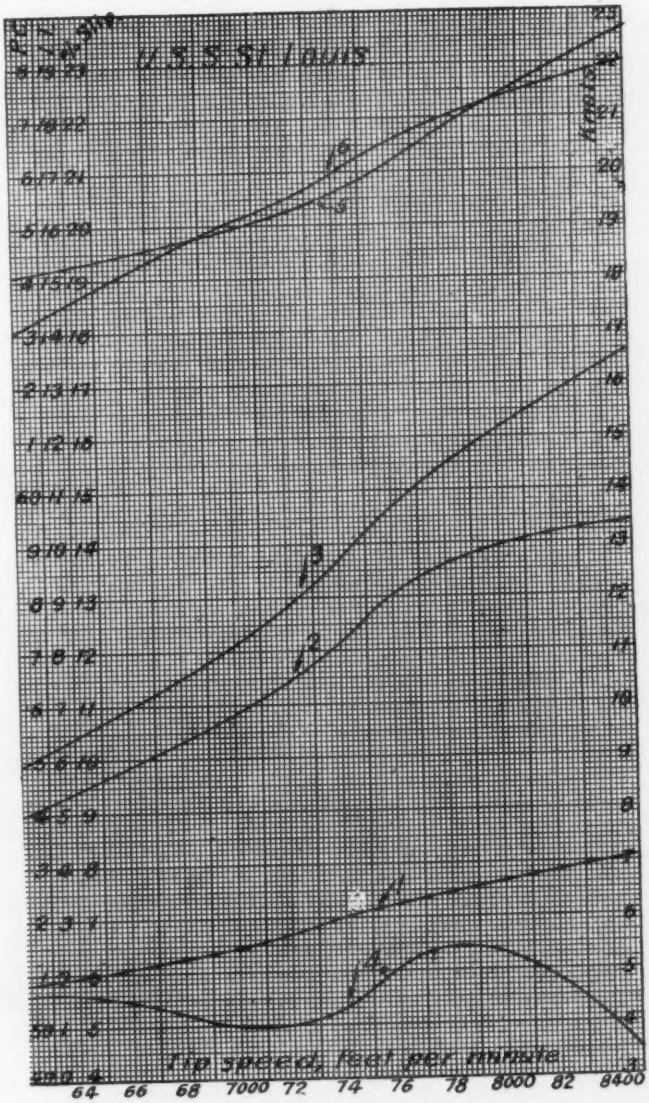


Plate 36.

Plate 35.

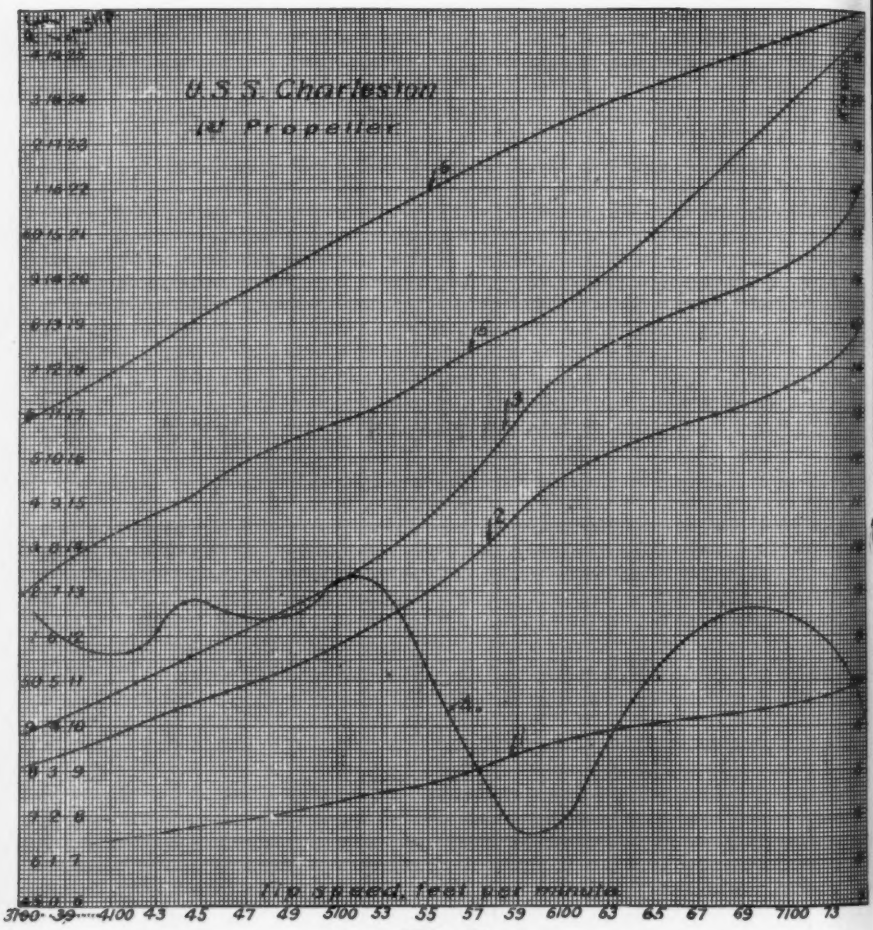

U.S.S. Charleston
18' Propeller
H.P.
R.P.M.
Thrust
Slip
H.P. Speed, feet per minute.
3100 39 4100 43 45 47 49 5100 53 55 57 59 6100 63 65 67 69 7100 73

Plate 37.

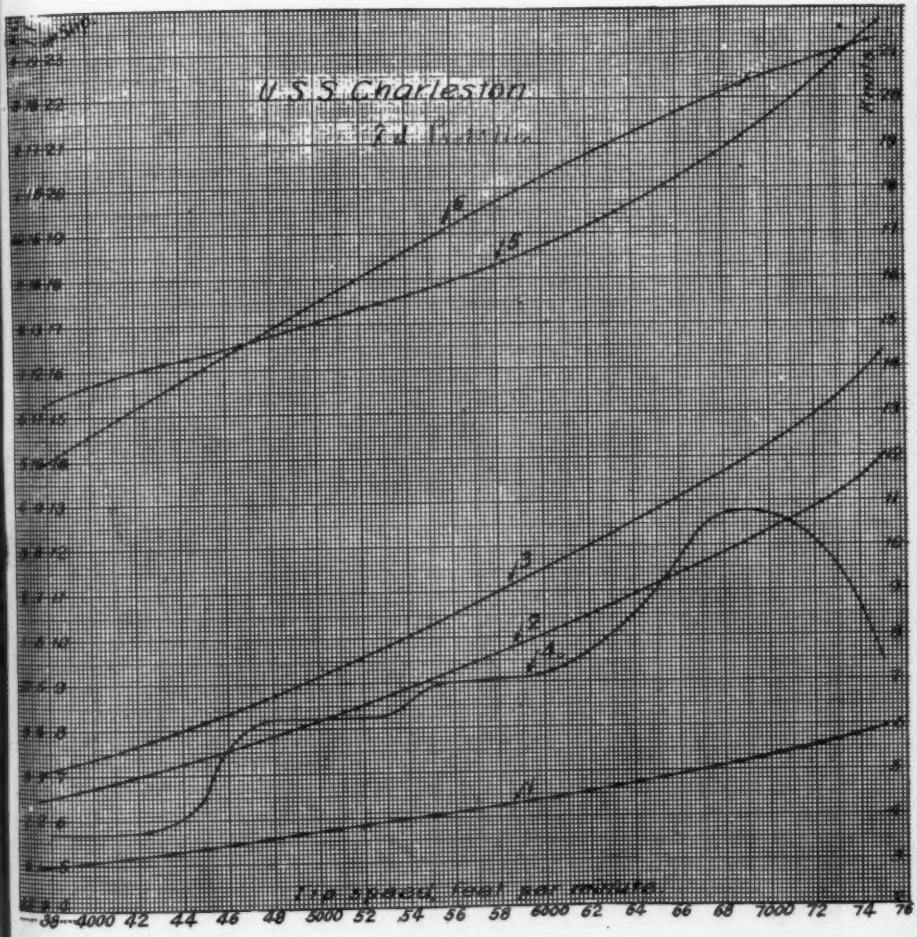
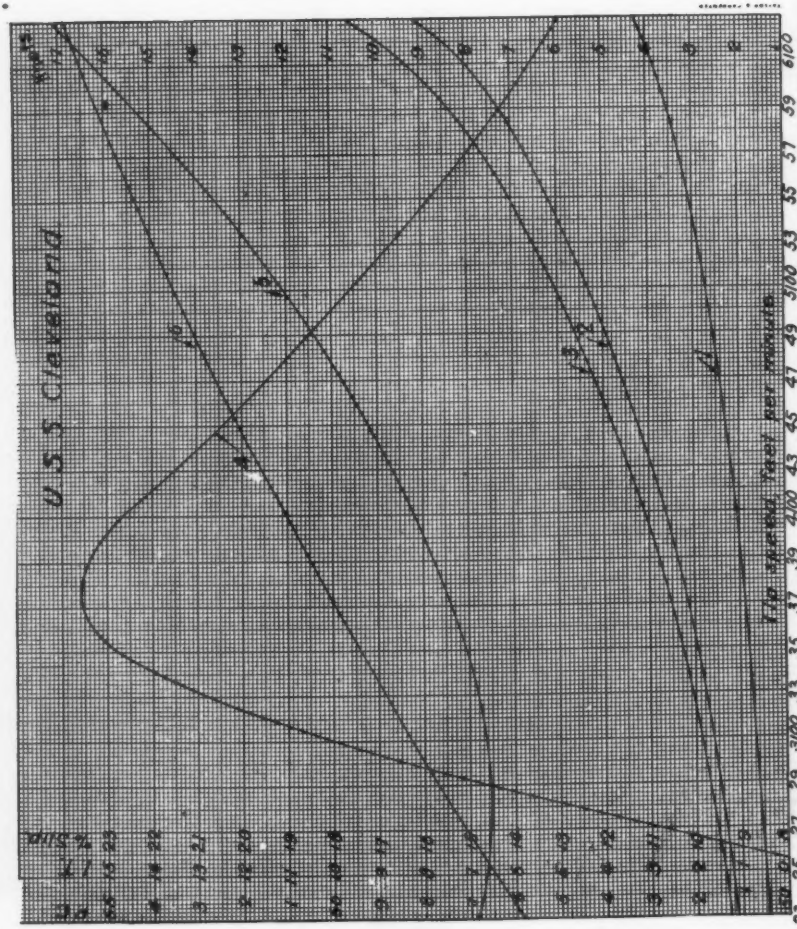


Plate 38.


U.S.S. Cleveland
Trip Starting Point per Indicator
Plate 39.

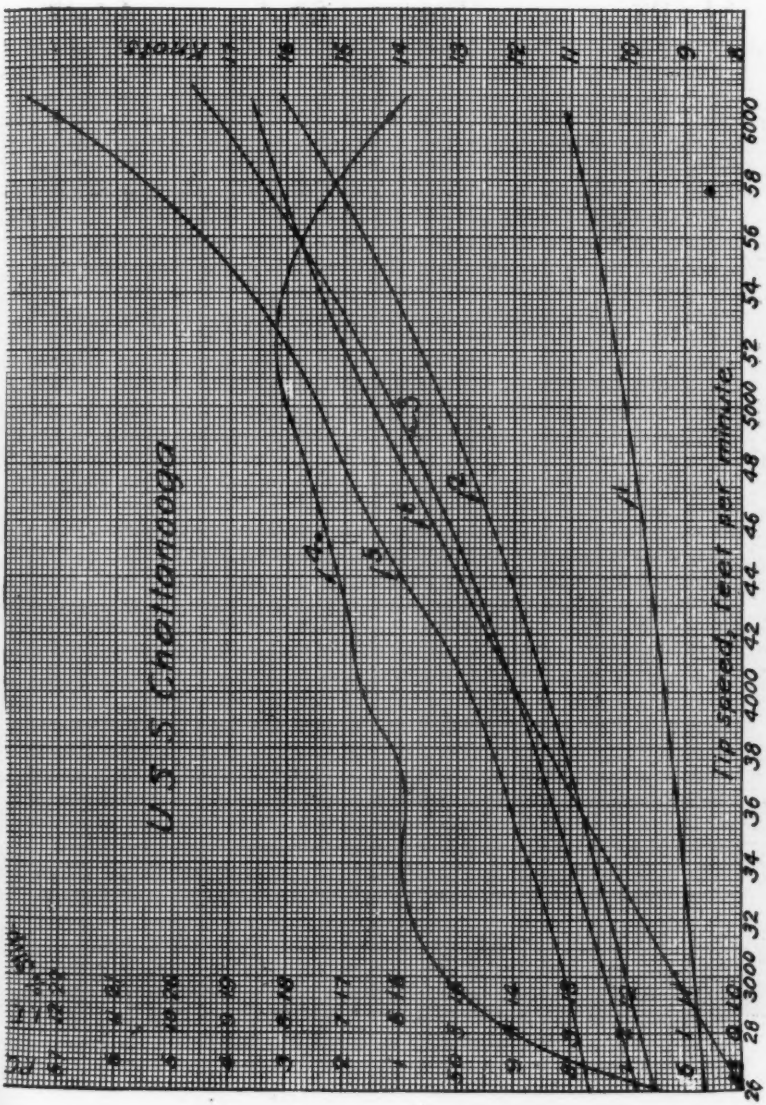


Plate 40.

Plate 39.

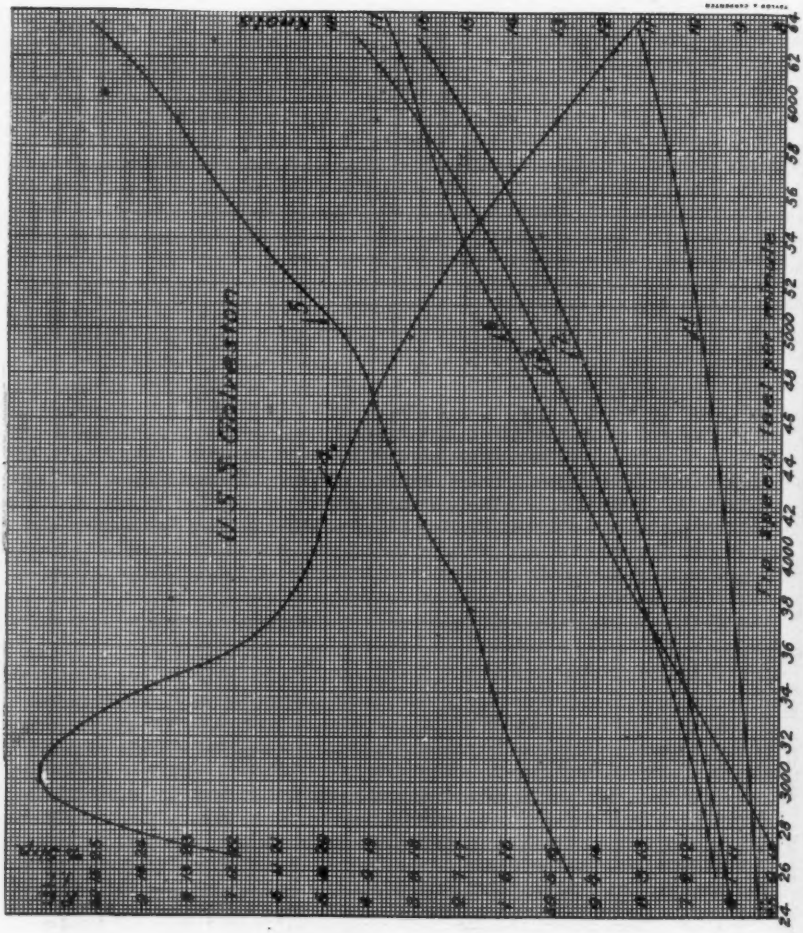

U.S.S. Galveston
For Speed for Revolutions
Knots
Revolutions per minute

Plate 41.

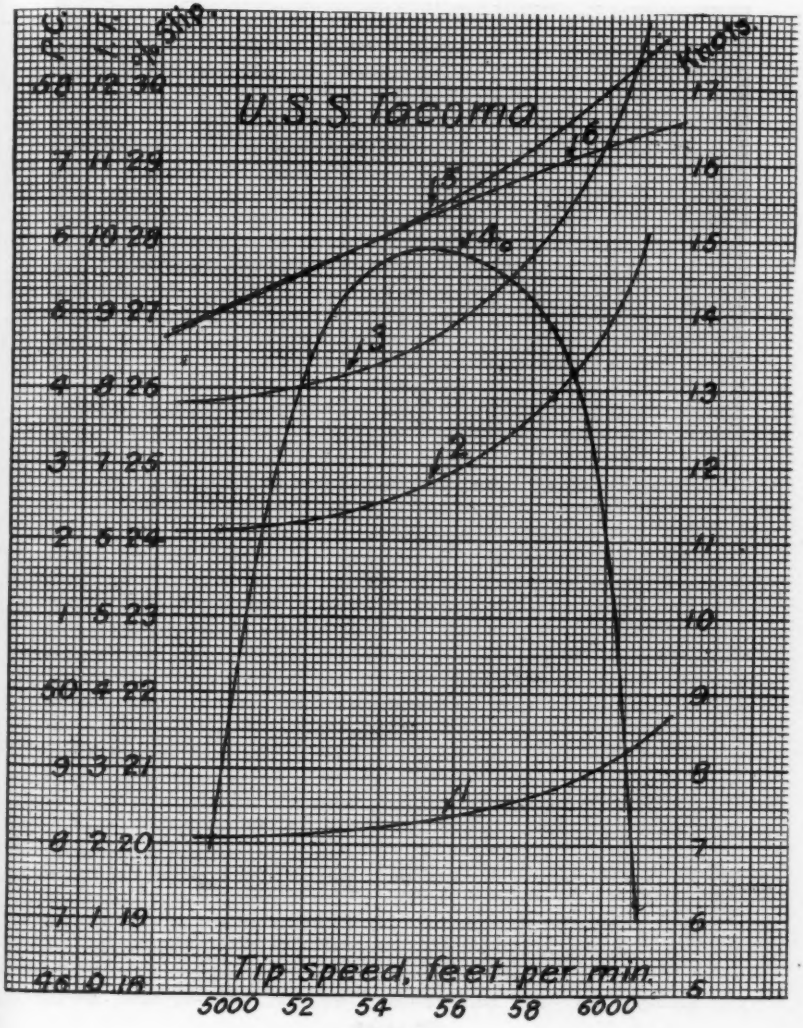


Plate 43.

Plate 41.

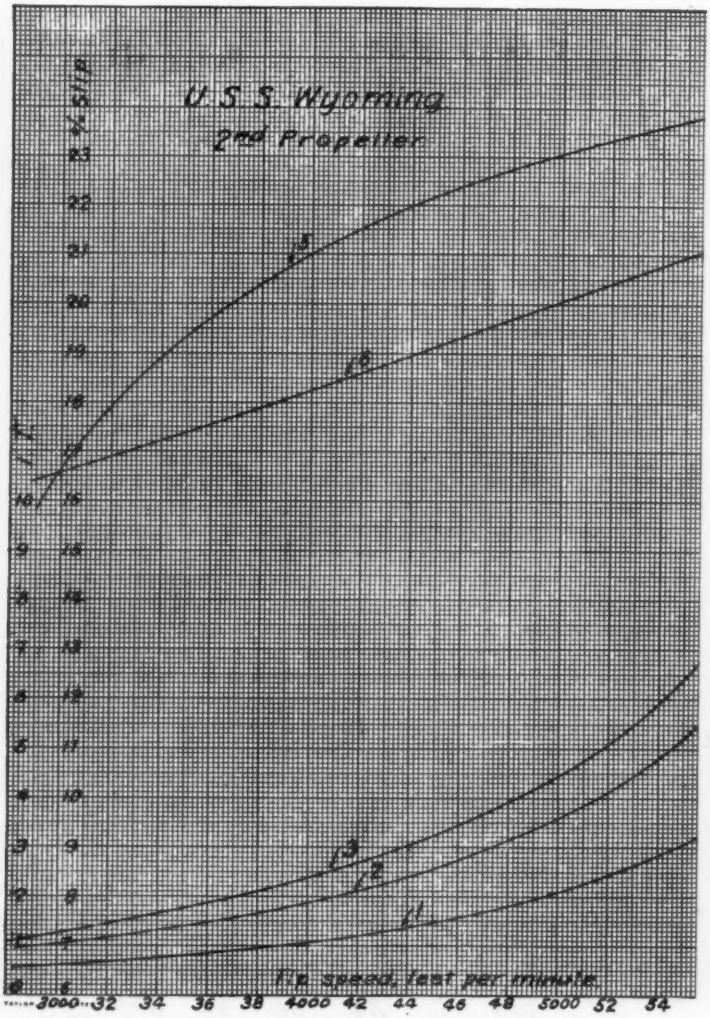

U.S.S. Wyoming
2nd Propeller
H.P.
Revs.
Slip
f/3
f/2
f/1
f's speed, feet per minute.
3000
32
34
36
38
4000
42
44
46
48
5000
52
54

Plate 45.

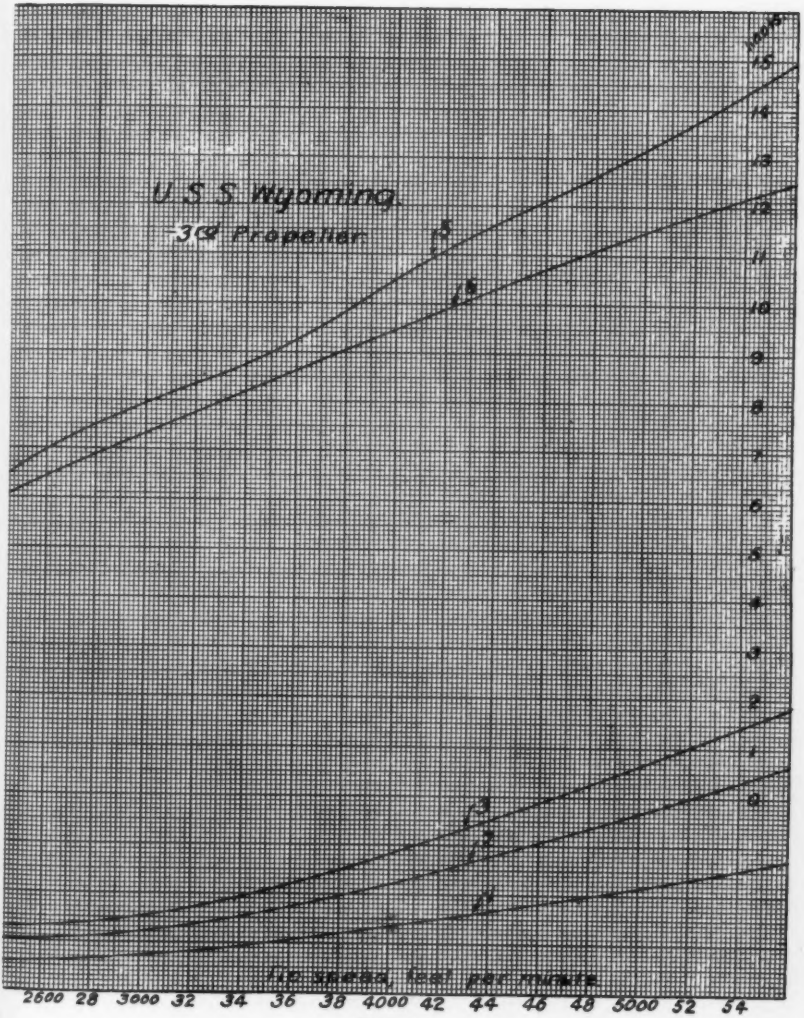

U. S. S. Wyoming.
3 Cyl. Propeller.
Tip speed, feet per minute.
2600 28 3000 32 34 36 38 4000 42 44 46 48 5000 52 54

Plate 46.

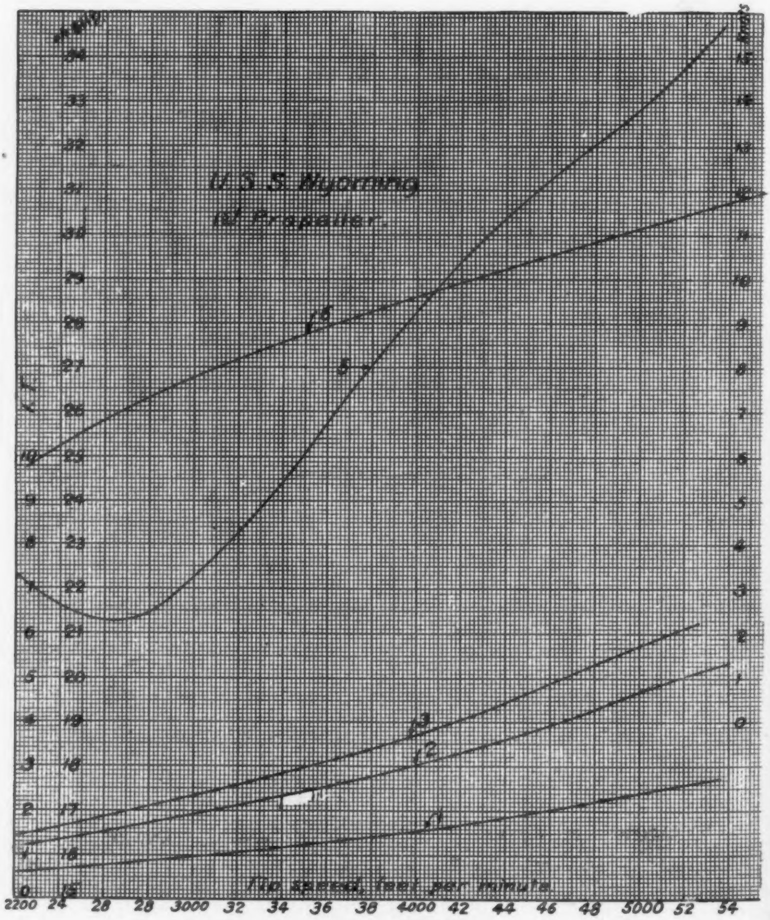

U.S.S. Wyoming
1st Propeller.
Tip speed, feet per minute
2200 24 26 28 3000 32 34 36 38 4000 42 44 46 48 5000 52 54

Plate 44.

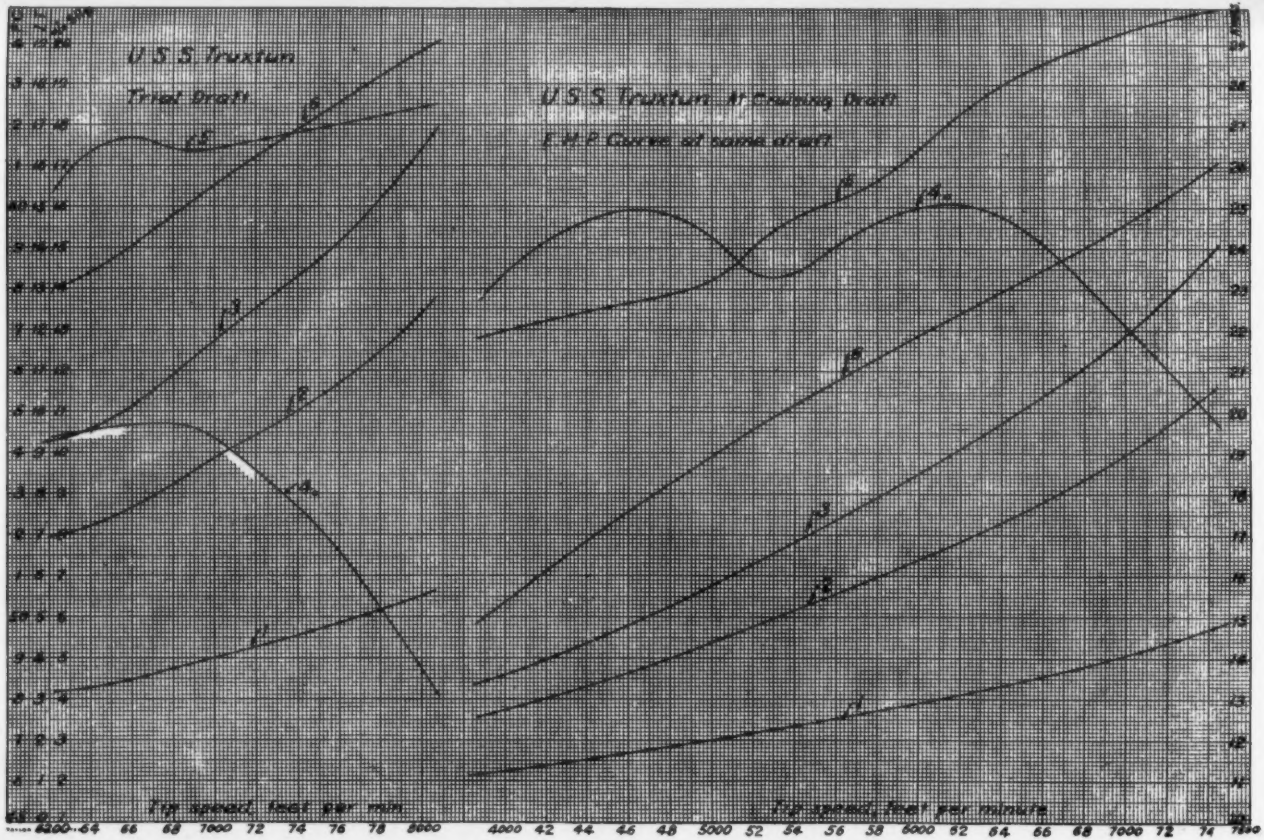

U.S.S. Truxtun
Trial Draft
U.S.S. Truxtun. At Cruising Draft
I.H.P. Curves at same draft
Trip speed, feet per min.
Trip speed, feet per minute

Plate 50.

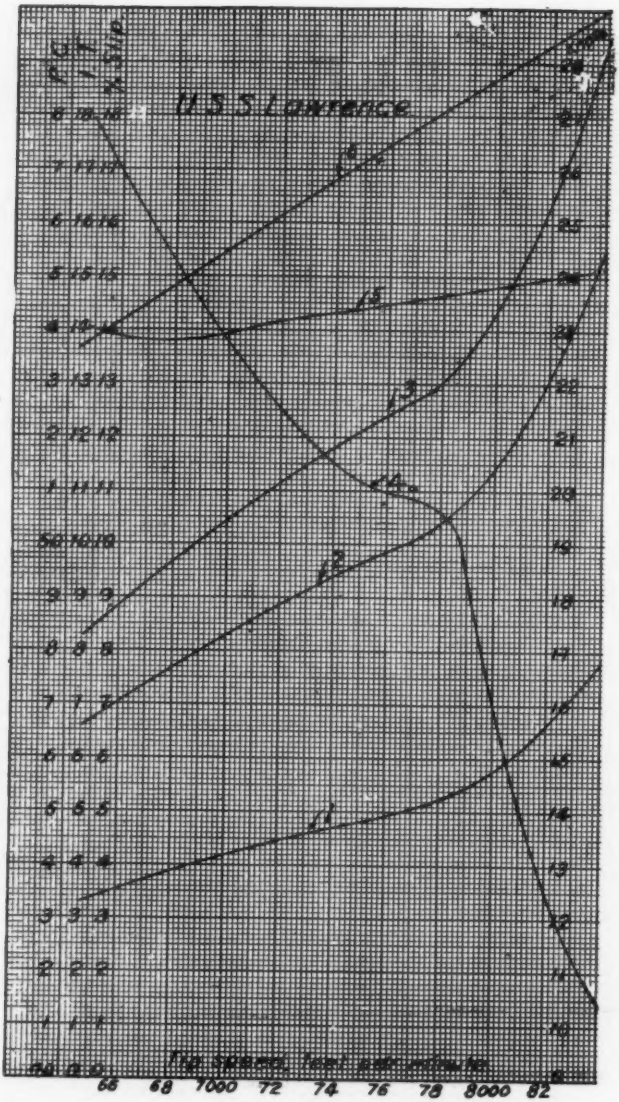


Plate 52.

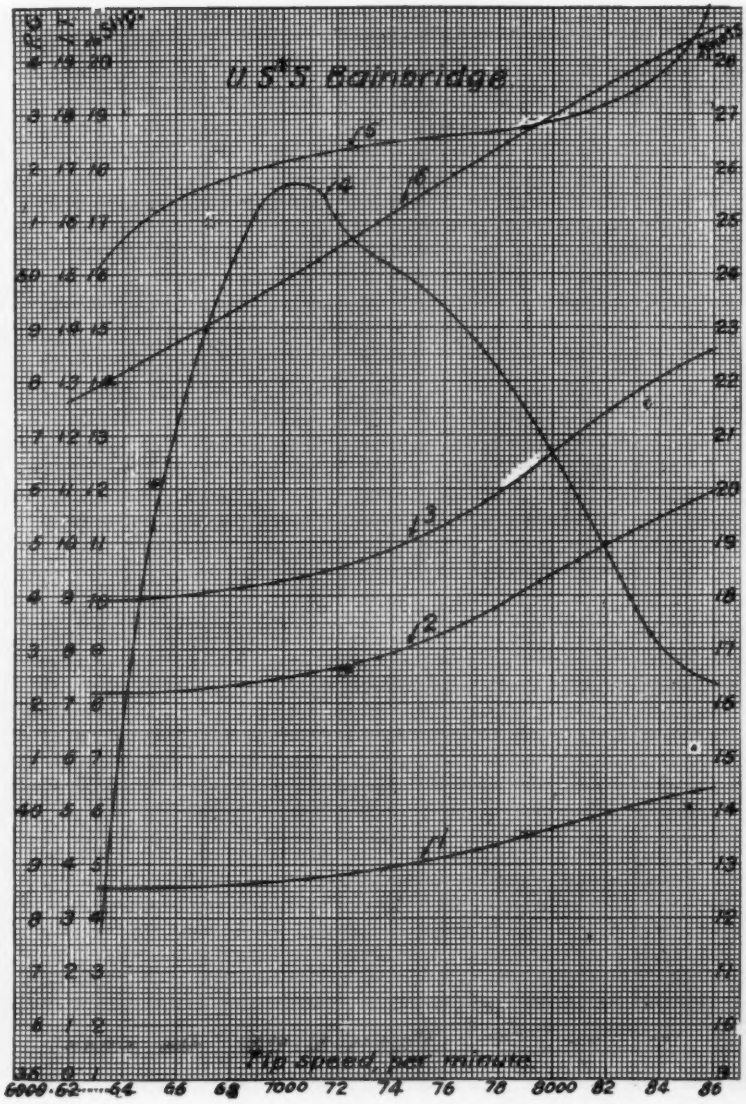


Plate 53.

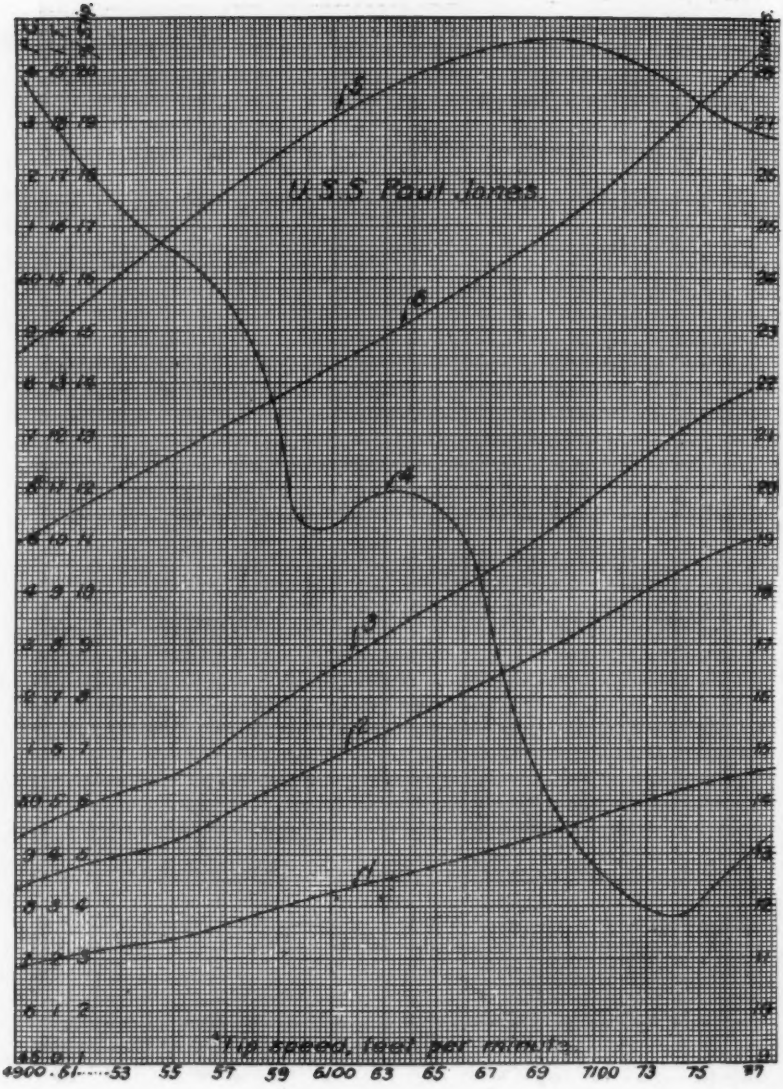

U.S.S. Paul Jones.
Tip speed, feet per minute.
4900
53
55
57
59
6100
63
65
67
69
7100
73
75

Plate 54.

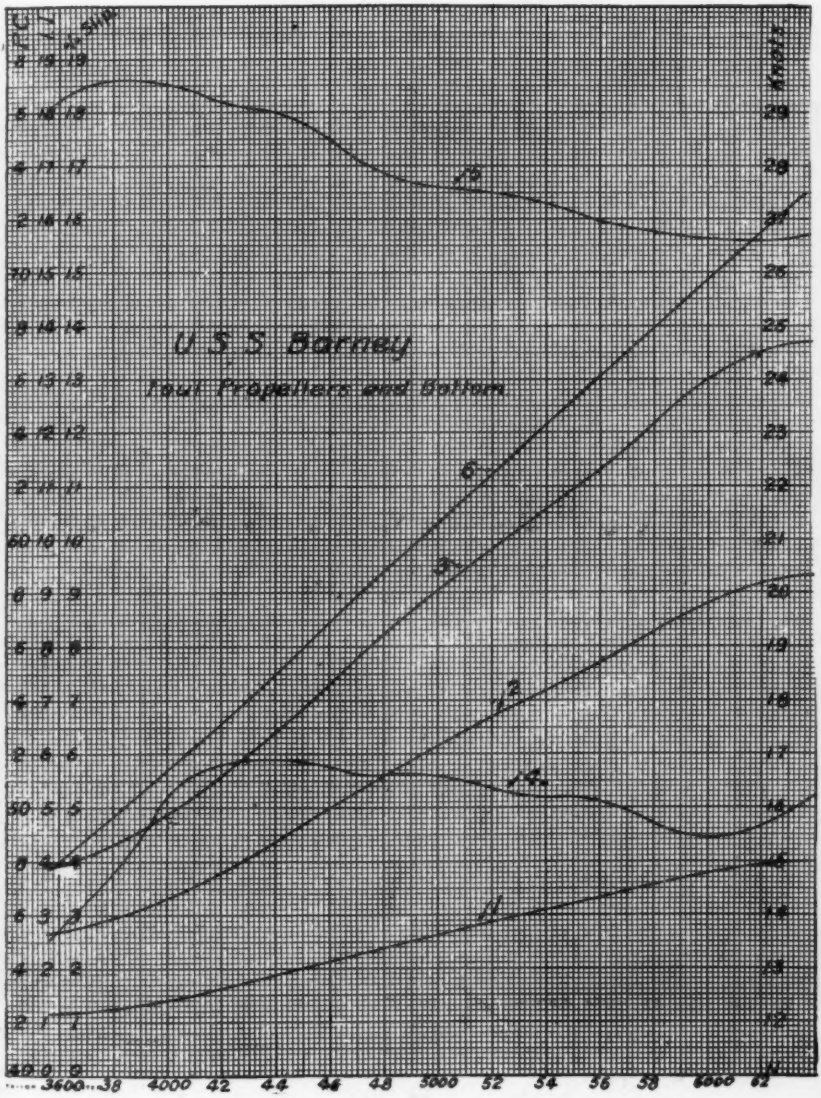

U. S. S. Barney
Foul Propellers and Bottom
Knots
Slip
3600
38
4000
42
44
46
48
5000
52
54
56
58
6000
62

Plate 54.

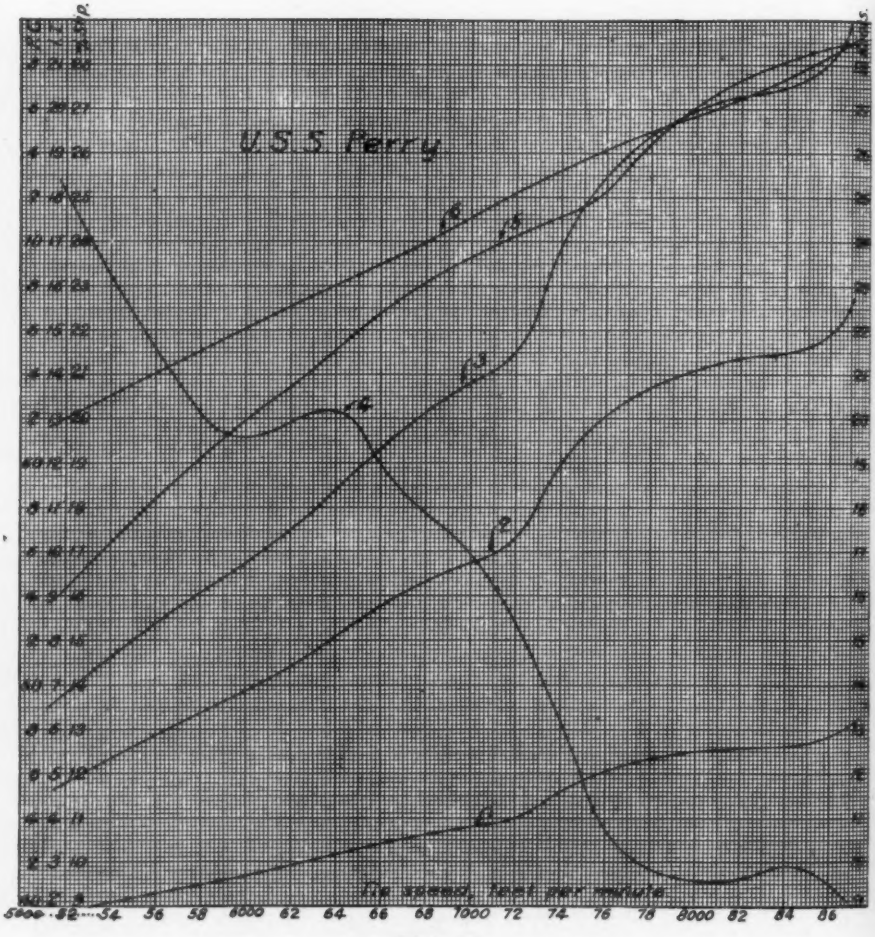


Plate 55.

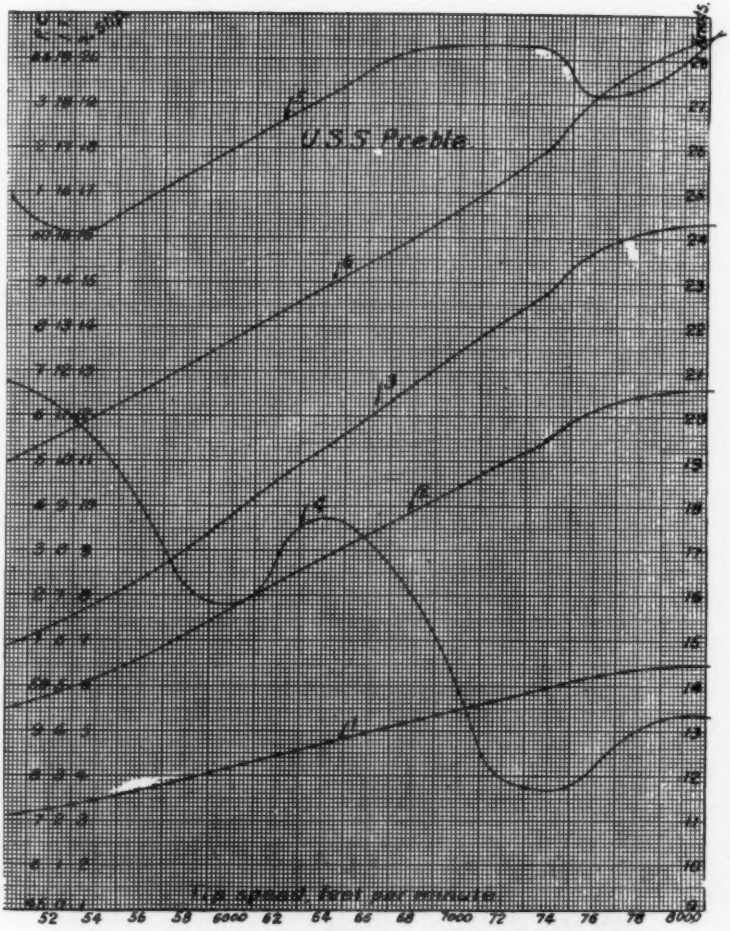

U.S.S. Preble.
Speed Feet per minute.
52 54 56 58 6000 62 64 66 68 7000 72 74 76 78 8000

Plate 56.

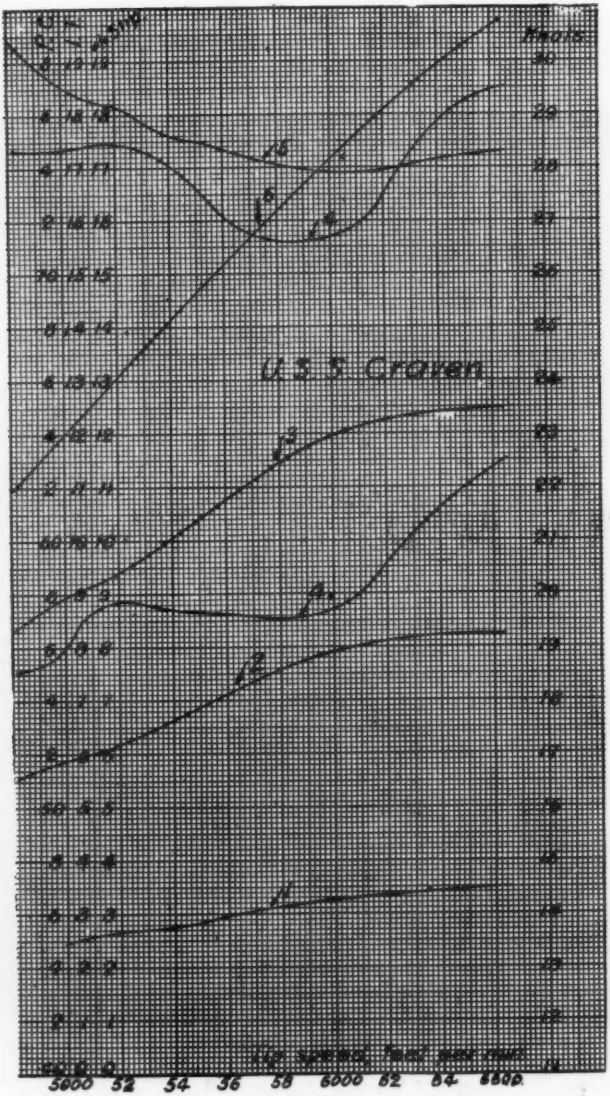


Plate 58.

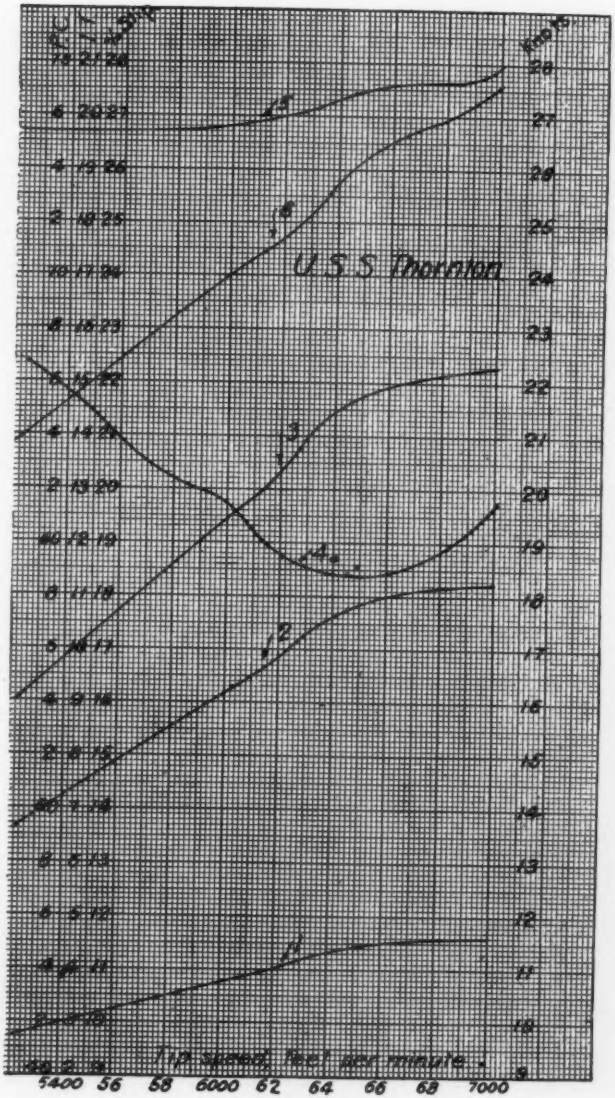
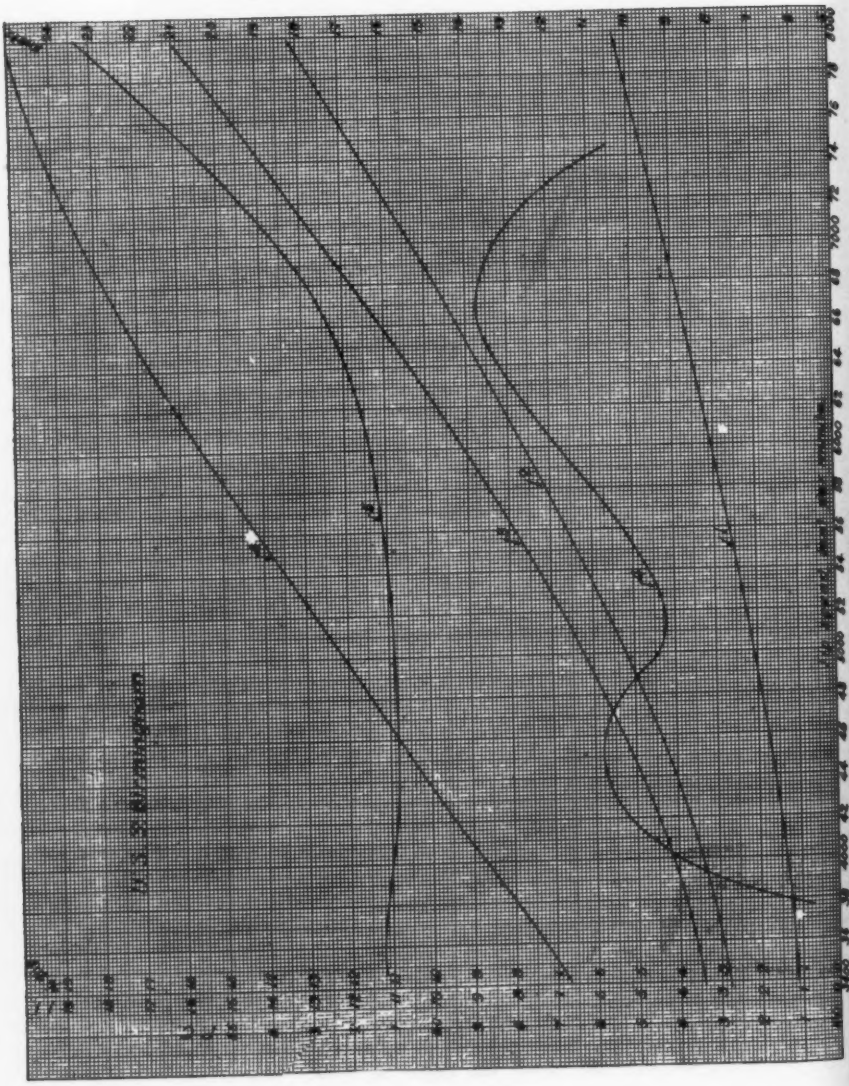

U.S.S. Thornton
Trip Speed, feet per minute.
5400 56 58 6000 62 64 66 68 7000

Plate 59.



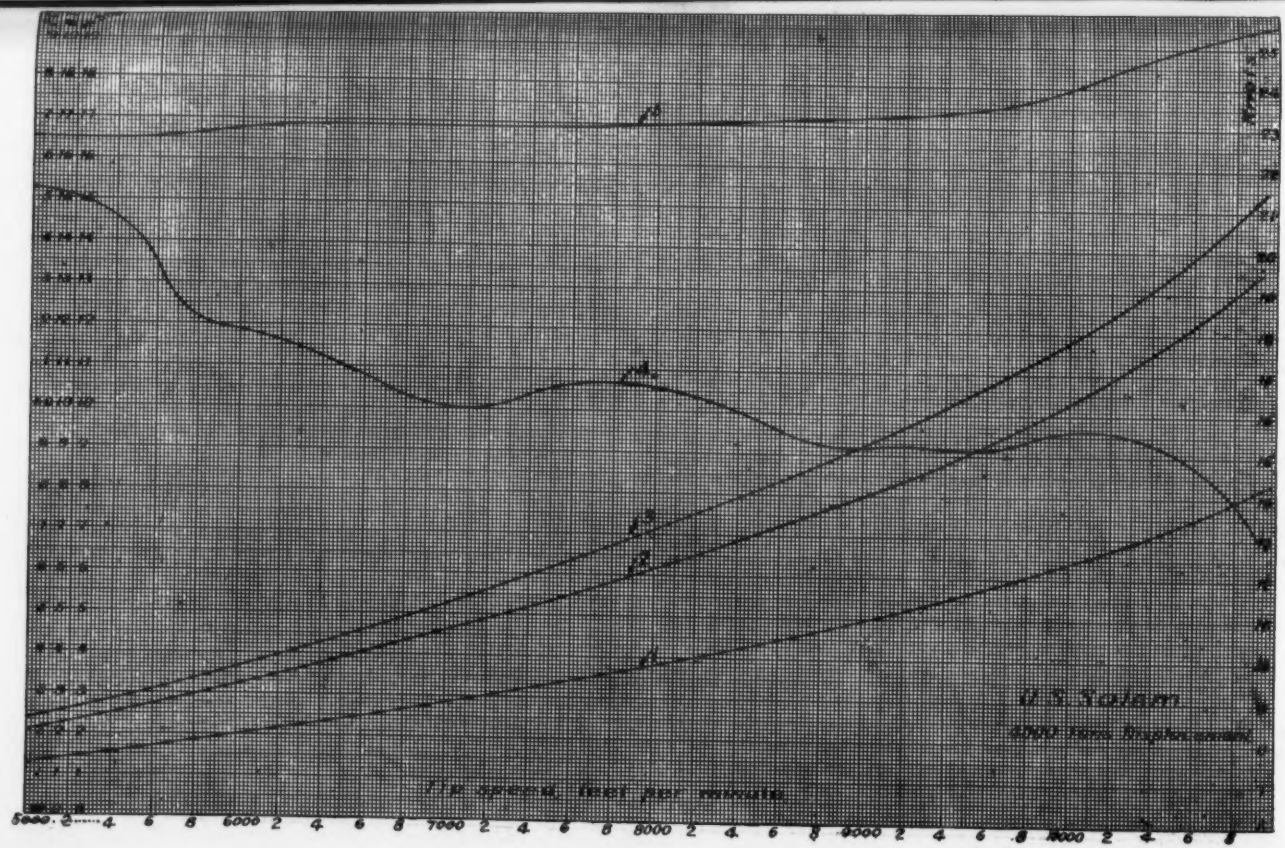


Plate 64.

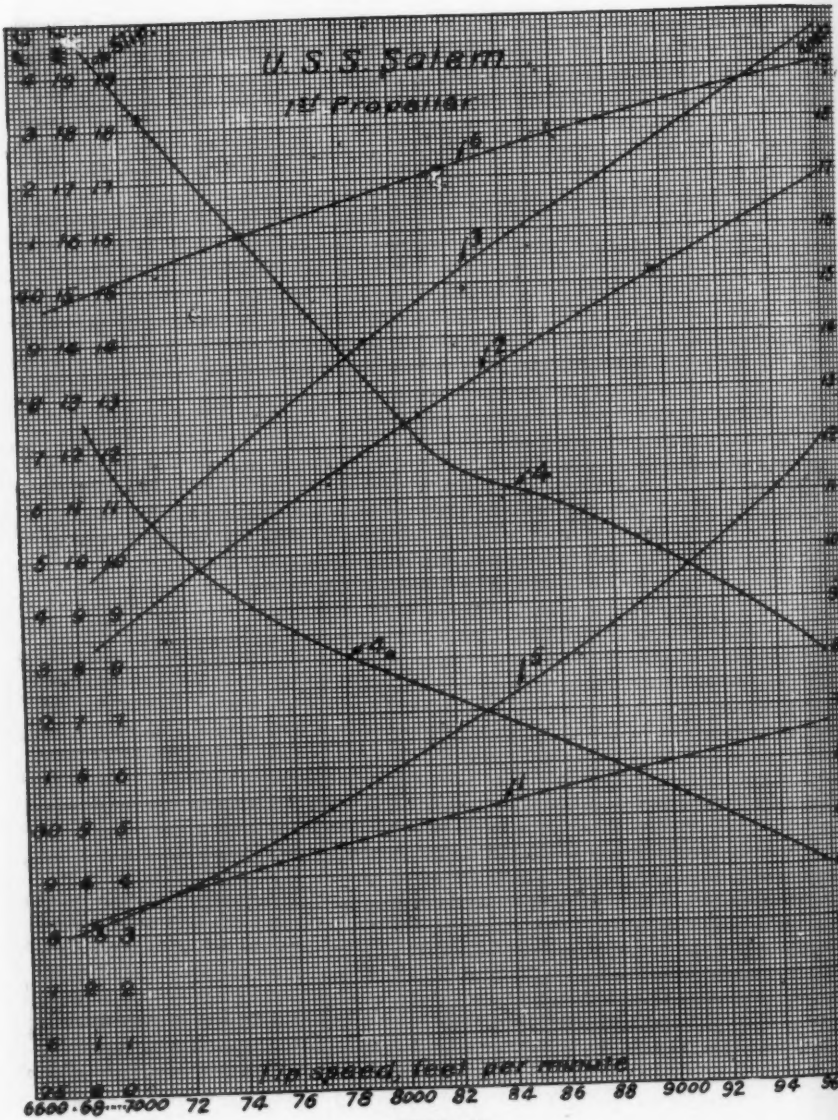

U. S. S. Salem
14' Propeller
Tip speed, feet per minute
6600 68 7000 72 74 76 78 8000 82 84 86 88 9000 92 94 9600

Plate 65.

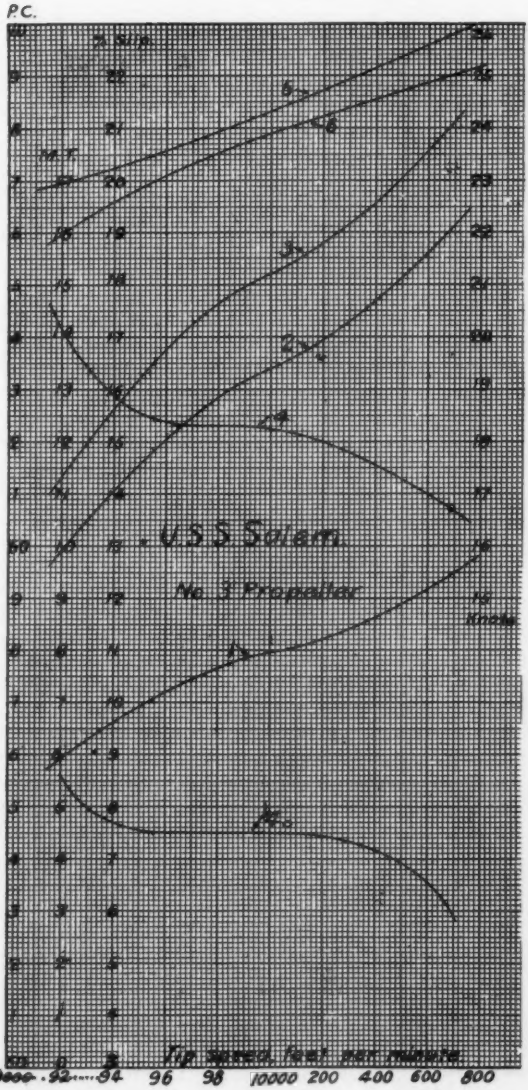

P.C.
U.S.S. Salem.
No. 3 Propeller
Knots
Tip speed, feet per minute.
92
94
96
98
10000
200
400
600
800

Plate 67.

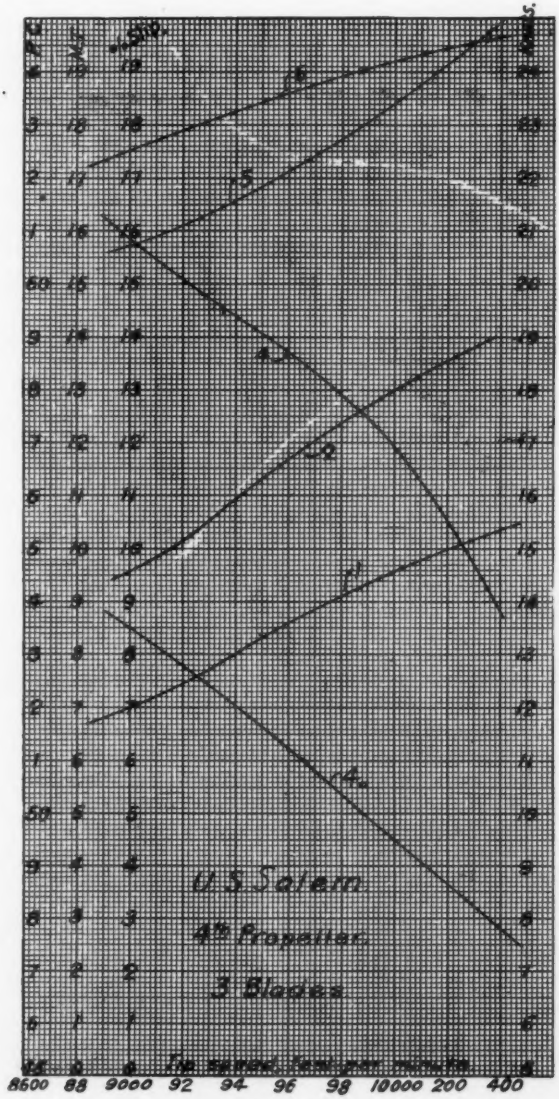
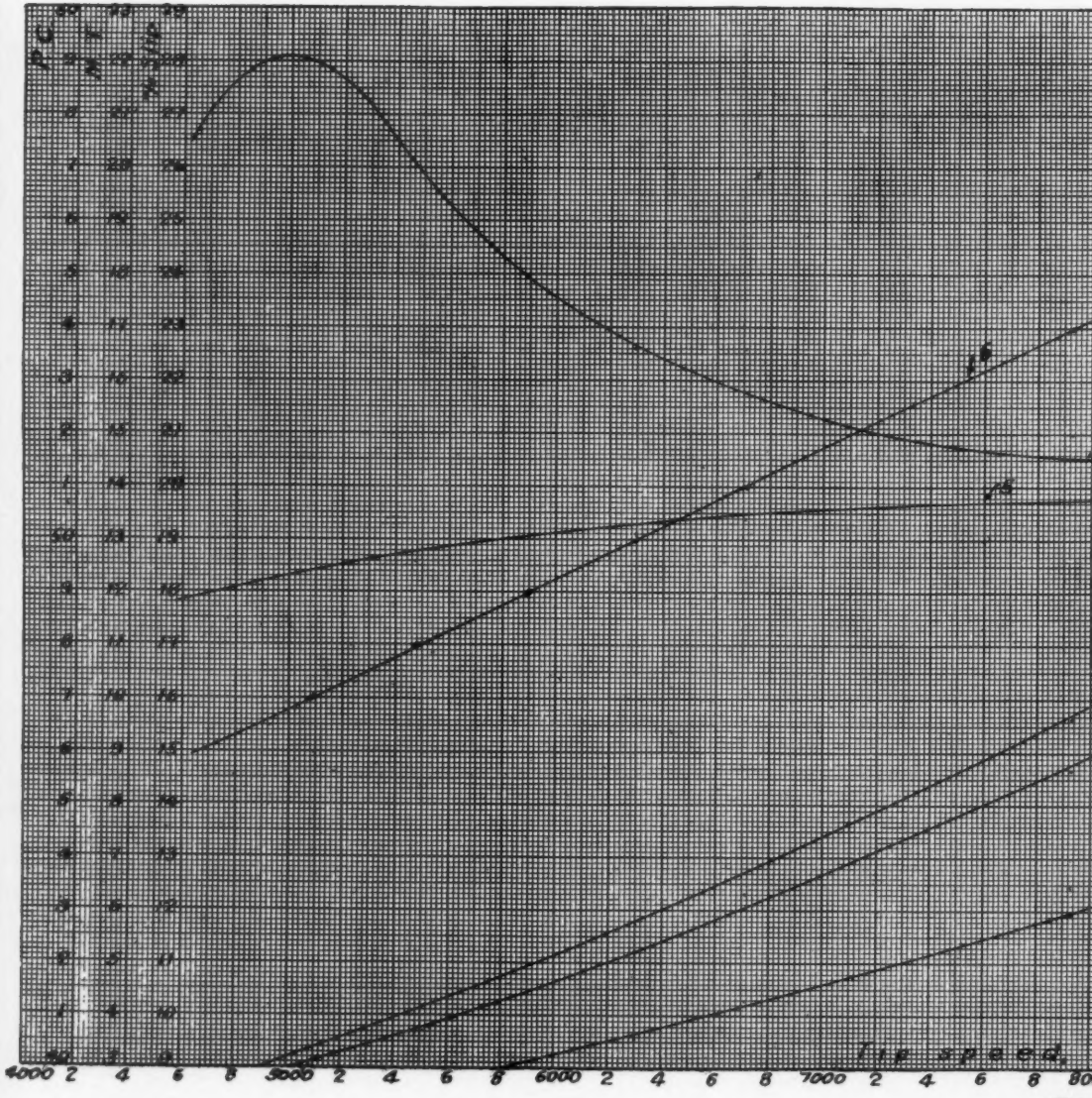

U.S. Salem
4th Propeller.
3 Blades.
8500 88 9000 92 94 96 98 10000 200 400

Plate 68.


4000
5000
6000
7000
Plate

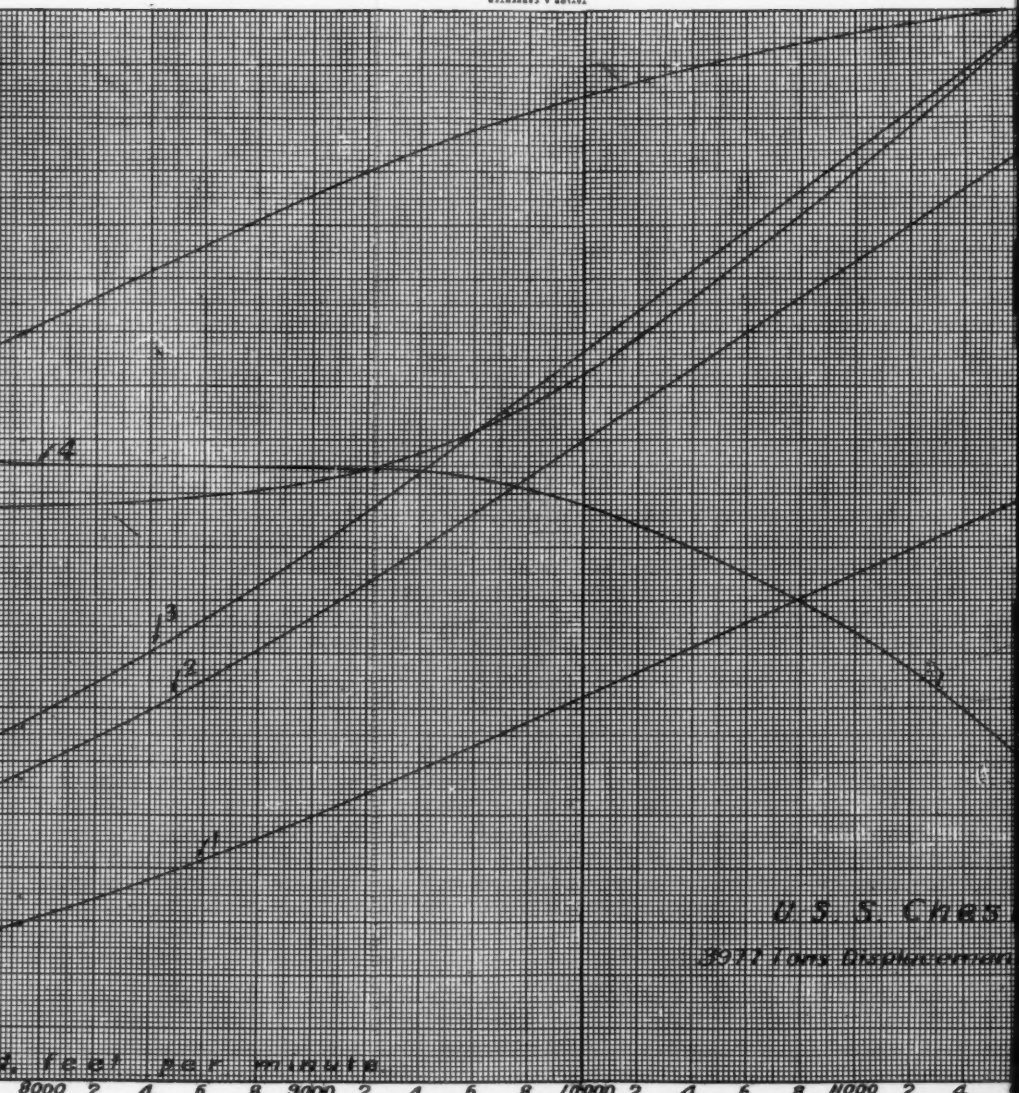

f4
f3
f2
f1
U. S. Ches
3917 Tons Displacement
feet per minute
8000 2 4 6 8 9000 2 4 6 8 10000 2 4 6 8 11000 2 4

Plate 69.

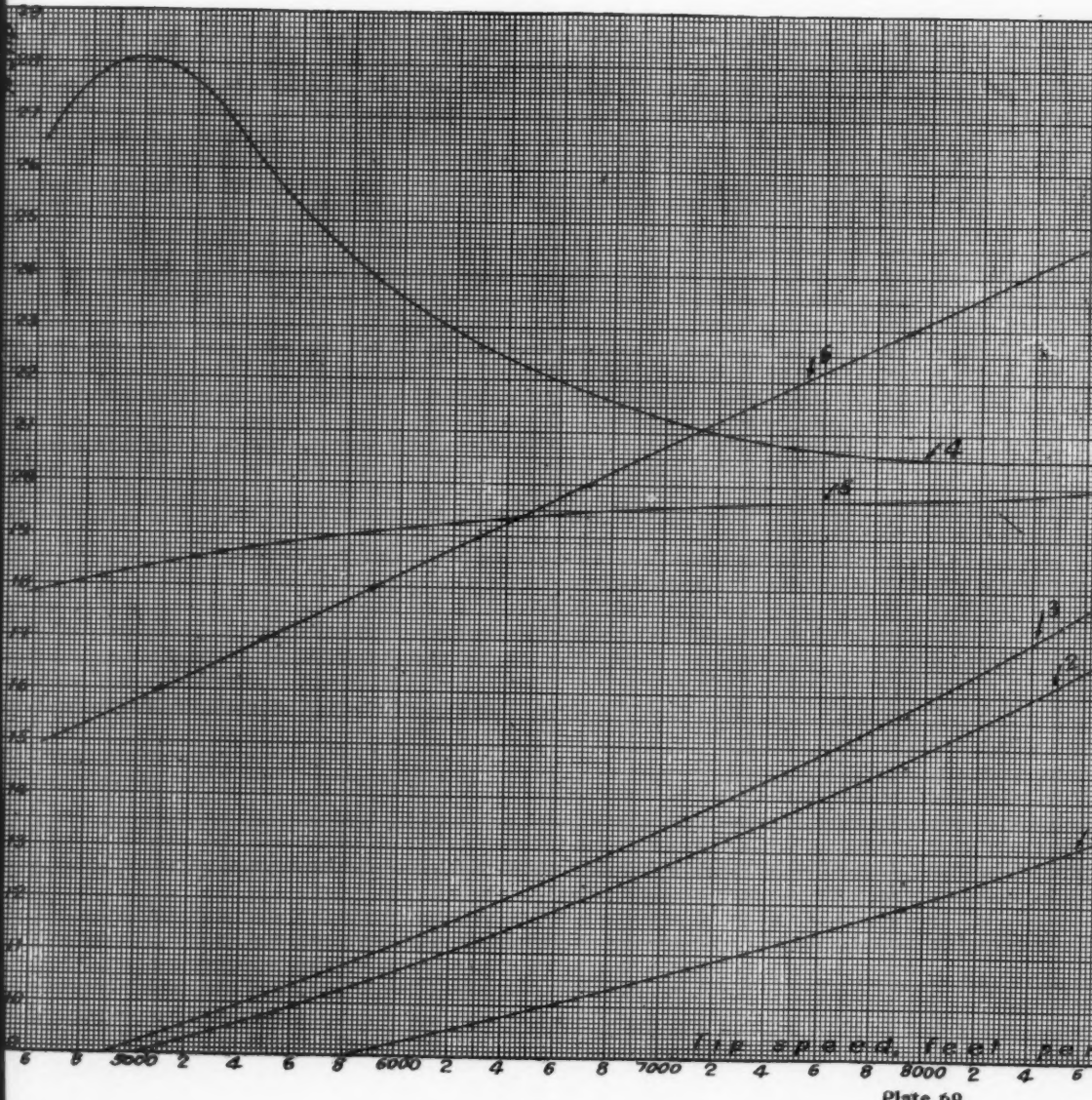
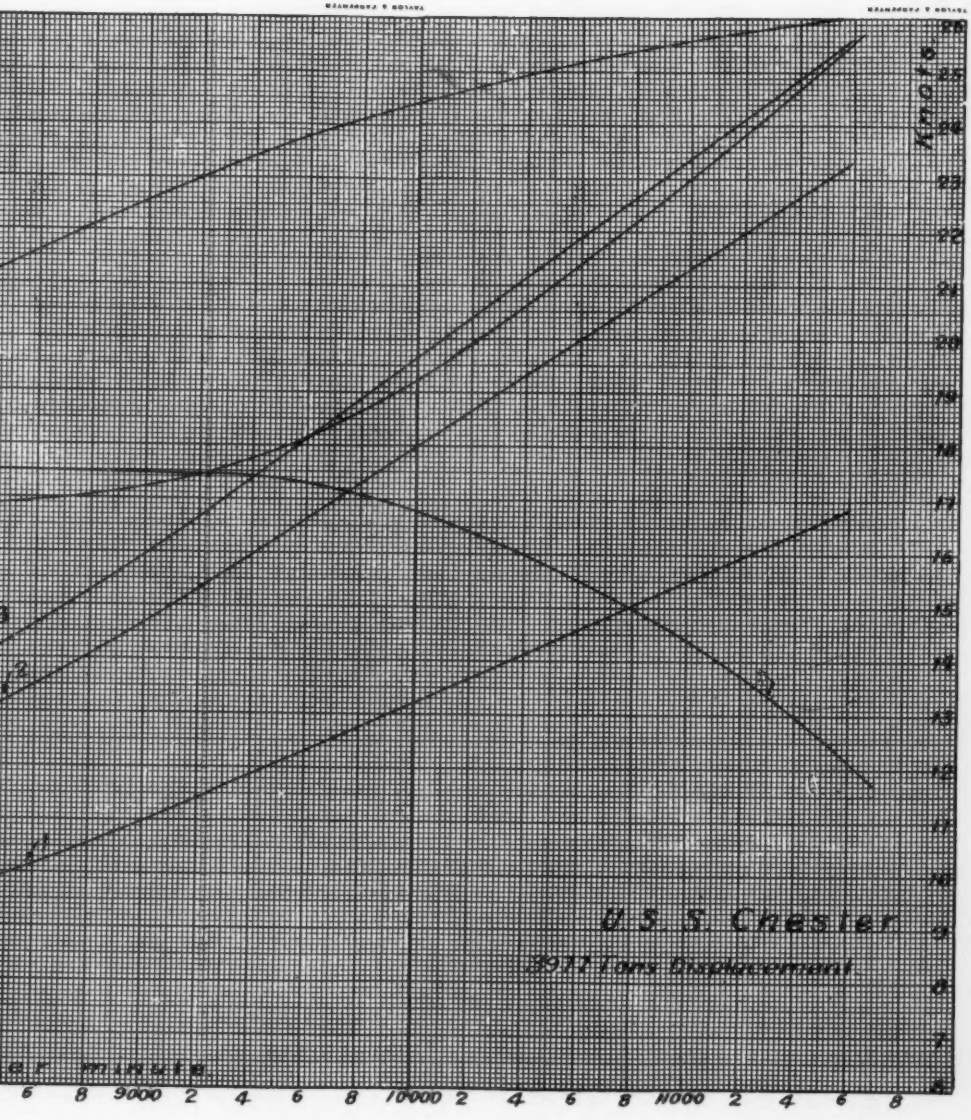


Plate 69.


U.S.S. Chester
3917 Tons Displacement
Knots
6 8 9000 2 4 6 8 10000 2 4 6 8 11000 2 4 6 8

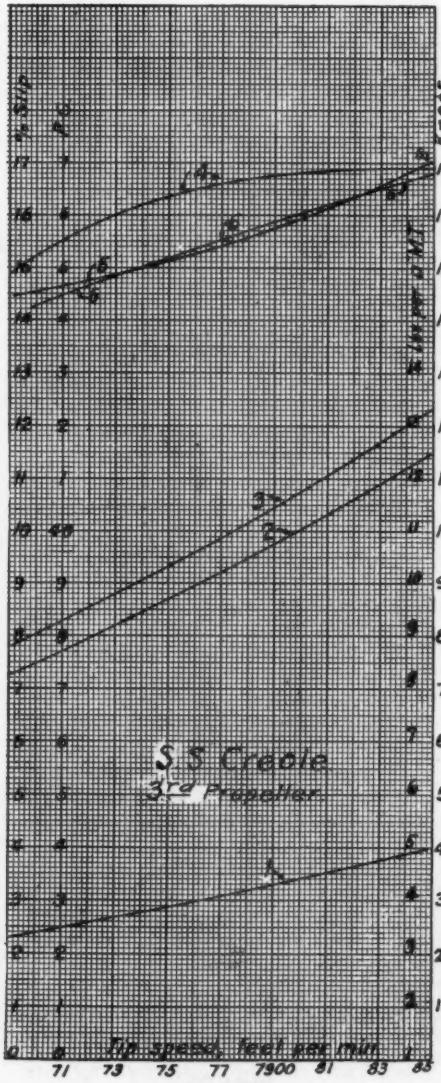

Slip
Knots.
S S Creole
3rd Propeller.
Fig. speed, feet per min.
71
73
75
77
7900
81
83
85

Plate 72.

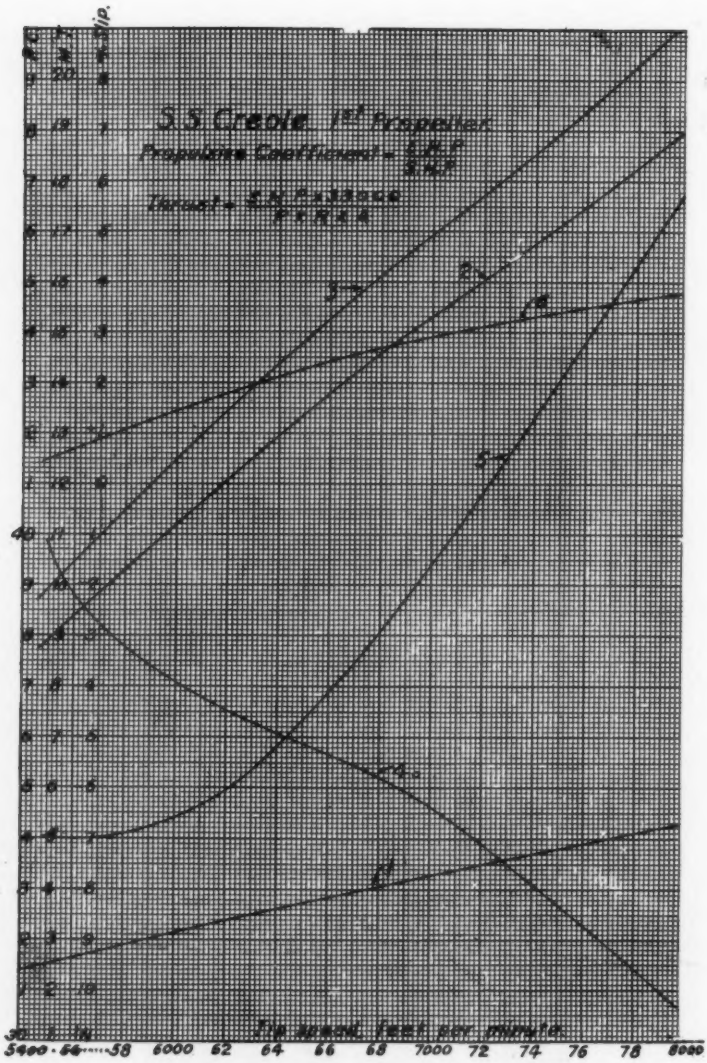

S.S. Creole 1st Propeller
Slip.
Fig. showing feet per minute.
5400
56
58
6000
62
64
66
68
7000
72
74
76
78
8000

Plate 70.

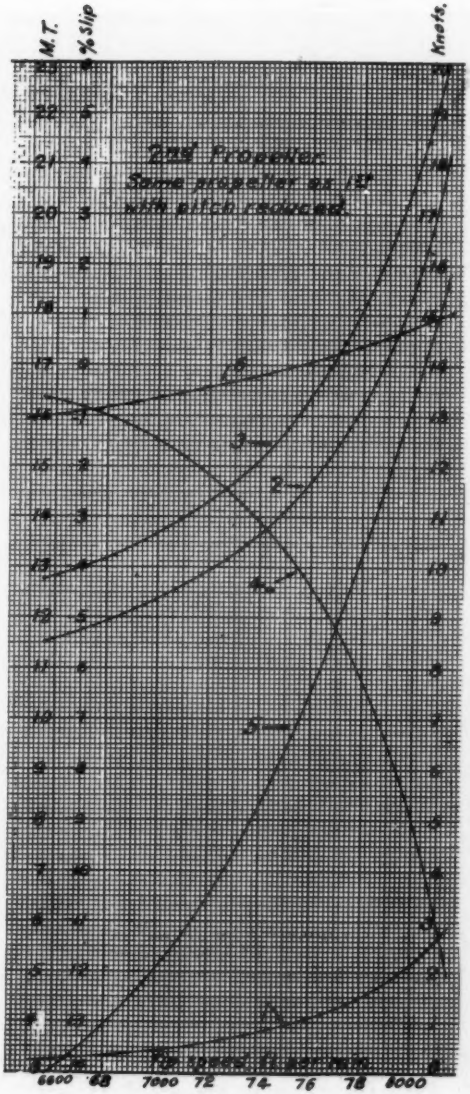

M.T.
% Slip
Knots.
2nd Propeller.
Same propeller as 1st
with pitch reduced.
1
2
3
4
5
6600
68
7000
72
74
76
78
6000

Plate 71.

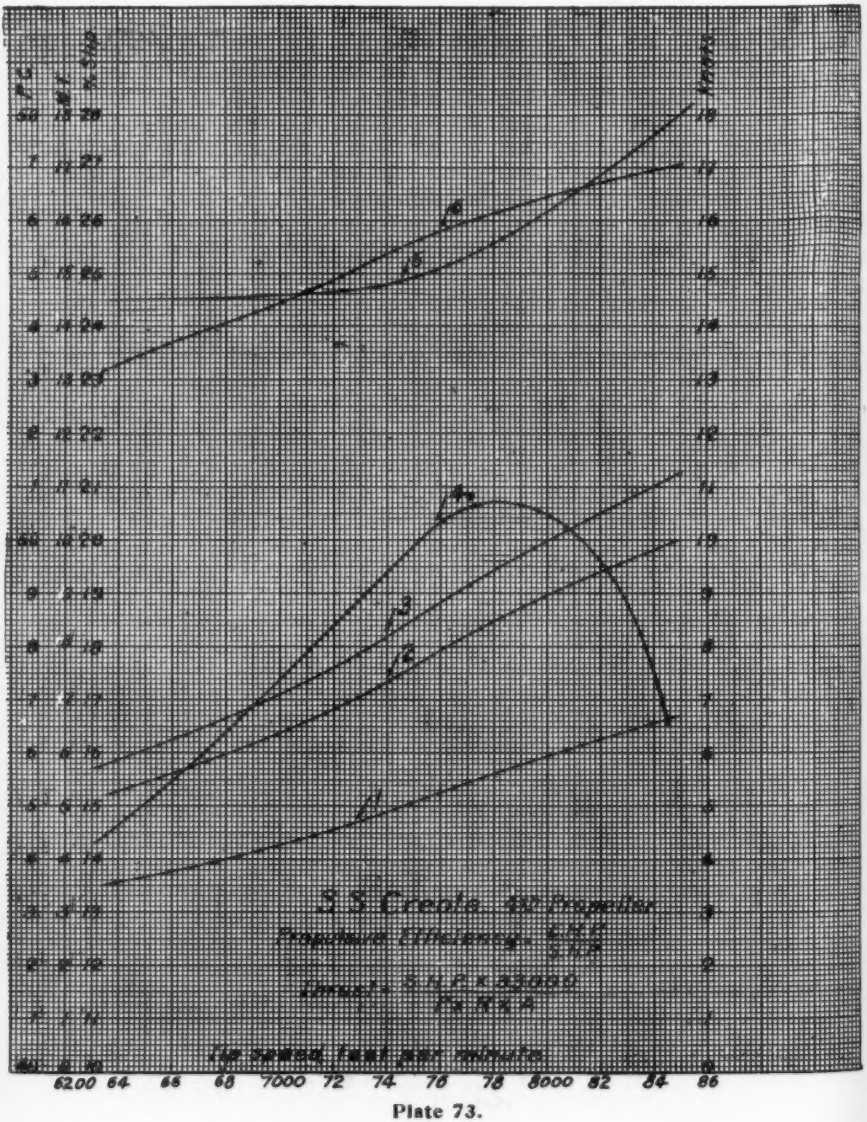

S. S. Creole. 22' Propeller.
Tip Speed, feet per minute.
6200 64 66 68 7000 72 74 76 78 8000 82 84 86

Plate 73.

NOTES.

SPECIAL NOTICE.

Short discussions and accounts of practical experiences on the following live points of engineering interest are requested, especially from officers serving at sea, communications to be published in the succeeding issues of the JOURNAL under heading of "Notes on Naval Engineering Practice":

1. What improvements should be made in operation of naval machinery tending to economy in consumption of coal, oil and supplies. It is desired that these subjects be treated under the general headings—

Firing, training of firemen and systems of firing employed.

Firing devices.

Adjustments of cut-off for economical working.

Boiler pressure for reduced powers.

Use or non-use of jackets, and difficulties attending their use.

Superheating.

Means for securing highest vacuum, and best operation of condensing apparatus, stoppage of air leaks into condensers, etc.

Saving in the operation of auxiliaries.

Economical methods of oiling, experiences with different oils, and saving in the use of engineering supplies.

Items of experience obtained with different supplies and material.

2. What means can be employed for best keeping naval boilers in efficient condition, touching on the points of corrosion, oil and dirt deposit, use of alkali and boiler compounds, and different methods of cleaning boilers.

3. What improvements should be made in the design and construction of naval machinery bearing upon the above points.

It is thought that by this means the benefit of recent experiments, discoveries, thought and discussion on matters affecting naval engineering subjects may be distributed to those intimately interested, and more general interest in the matters developed among the members of the Society and the readers of the JOURNAL.

It is earnestly hoped that all readers having at hand any novel or interesting information or experience on these or any similar topics may jot them down and send them along. Photographs or sketches (even if rough) illustrating such notes will be gladly welcomed. Much valuable, novel and interesting information exists in the Service, and if the JOURNAL can secure some of it in this manner and distribute it to the engineering personnel of the Naval Service and to its Civil Associates one of the main purposes of this Society will be accomplished.

Members of the Society are also requested to use their best efforts in securing new members, and thus increase the field of usefulness of the Society and the value of the JOURNAL.

The coöperation of every officer in any way interested in Naval Engineering is desired, and such assistance on the part of Members will contribute to the progress of engineering and add to the engineering ability of the personnel of the Navy.

It is the purpose of the Society to secure the best possible matter of professional interest and to pay for contributions of value so as to make the JOURNAL as interesting and attractive as it is possible.

H. C. DINGER,
Secretary-Treasurer.

RETROSPECT FOR YEAR 1908.

NAVAL AND MILITARY.

In a review of the naval events of the year, the two facts which stand out with prominence, at least as far as the United States is concerned, are the remarkable cruise of the Atlantic Squadron around the world, and the acrimonious controversy which has been aroused as to the efficiency of the Navy. The sweeping criticism of our ships had its origin among a few of the more progressive and ambitious of the younger men among the seagoing officers. The motives which prompted this criticism were, we believe, honorable and distinterested; but the manner of their presentment was about as unfortunate and deplorable as it could well be, the medium chosen being a popular magazine, and the writer a layman who allowed his zeal to run away with his discretion, and offered his arguments in a manner so marked by exaggeration and extravagance that he defeated the very object in view. That the ships of our Navy are capable of improvement in certain particulars is undeniable; and had these improvements been suggested with moderation and a strict agreement with the facts, the criticisms would have been heard, and the ultimate results more quickly secured. In the long-drawn-out controversy which has ensued the most important of the alleged defects have been disproved, and the fact established that our battleships are fully comparable with the ships of foreign navies of the same date of design. At the Newport Conference, which followed a few months after the Senate inquiry, it was also proved, if proof were necessary, that the designs of our latest ships of the *Dreadnought* type were not only abreast of the times, but that they have served in some particulars as a type which other naval powers are closely following. Perhaps the most significant tribute to the excellence of our Navy was the punctual arrival of the battleship fleet at the various ports of call, and the even more important fact that the fleet today, in spite of its long and arduous cruise, is in excellent condition, the deterioration being only such as is inevitable in any fleet on a cruise of

this great duration. Progress in the upbuilding of our Navy during the year has been very satisfactory. The three scout cruisers, *Birmingham, Chester* and *Salem,* have passed through their trials successfully. These vessels, of 4,580 tons displacement, were designed for a trial speed of 24 knots. The *Birmingham,* equipped with twin reciprocating engines, averaged 24.32 knots on her four-hour trial; the *Chester,* furnished with Parsons turbines, made 26.52 knots; and the *Salem,* equipped with Curtis turbines, averaged 25.94 knots. These three ships are about to engage in a series of competitive trials, which will furnish data of unusual interest. During the year all of our battleships under construction, except those of the *Dreadnought* type, have been completed, with the result that of the later designs we now possess six *Connecticuts,* of 16,000 tons and 18 knots; two smaller *Connecticuts,* the *Idaho* and *Mississippi,* of 13,000 tons and 17 knots; and five *Virginias,* of 15,000 tons and 19 knots speed. All of these ships carry modern 12-inch guns in the main battery, and a heavy intermediate battery of 8-inch guns. We have six *Dreadnoughts* under construction. The *South Carolina* and *Michigan,* of 16,000 tons, carrying eight 12-inch guns, are about two-thirds completed; the *North Dakota,* 20,000 tons, carrying ten 12-inch guns, has recently been launched; and her sister, the *Delaware,* will shortly take the water. The slips are now being prepared for the laying down of the 20,000-ton *Florida* and *Utah.* The last report of the Chief of the Bureau of Ordnance states that our 45-caliber 12-inch gun is fully the equal of any mounted in any foreign Navy; but in view of the fact that some of these navies have 12-inch 50-caliber pieces under construction, whose muzzle velocity will be from 3,000 to 3,100 foot-seconds as against 2,700 foot-seconds for our guns, it is evident that a new 12-inch piece should be designed. On the other hand, there is a movement on foot favoring the arming of our future *Dreadnoughts* with a new 14-inch piece; and it has been suggested that our next appropriations should be either for 20,000-ton ships carrying eight 14-inch guns, or 23,000-ton ships carrying ten 14-inch guns. Outside of the construction of

battleships, our efforts are being devoted to the construction of seagoing torpedo boats and submarines. The United States is building no armored cruisers. The crying need of the Navy today is for a fleet of large, fairly fast colliers. The Atlantic fleet, on its trip around the world, has to depend almost entirely on foreign tramp steamers for its coal supply. In time of war these would not be available. We have no merchant marine to speak of; and, in its absence, the construction of a fleet of colliers is as essential as the construction of battleships. Great Britain, with a total displacement of armored ships of 1,395,930 tons, continues to lead the world in the number, power and quality of her ships, the United States being second with 607,241 tons, and France third with 573,364 tons. If battleships alone be reckoned, Germany takes third rank. Great Britain records no failures. She serves as the great experimental ground for the world, and the ships which she evolves seem to stand as types for other nations. The *Dreadnought* has been followed by six other ships of the same general design, in which have been incorporated the experience gained during the extensive cruises of the *Dreadnought*. Hitherto the British have not followed our system of mounting the 12-inch guns on the central line of the ship; though it is rumored that in their next ships they will incorporate this valuable feature. The most sensational success of the year was the brilliant performance of the battleship-cruisers *Invincible* and *Indomitable*. Both of these, on their trials, made over 27 knots an hour, and the *Indomitable* crossed the Atlantic from Newfoundland to Southampton at an average speed of a fraction under 25 knots an hour. Sensational, also, were the speeds achieved by what is known as the tribal class of torpedo-boat destroyers, vessels of 750 tons, which steamed for six hours at average speeds of from 34 to 35.36 knots an hour, the *Tartar* on one run reaching a speed of slightly over 37 knots. Later in the year the ocean-destroyer *Swift*, of 1,800 tons, maintained for some hours a speed of 38.3 knots, or between 44 and 45 miles an hour. It is probable that the next radical departure in warship construction will be the adoption of gas engines for motive power.

Yarrow & Co. built during the year two 250-horsepower gasoline-propelled gunboats for the Austro-Hungarian Navy, and Beardmore & Co., of Glasgow, have equipped an old British gunboat, the *Rattler,* with producer-gas engines, which, compared with the old steam plant, show a large saving in weight and fuel consumption and have driven the ship at a speed of between 11 and 12 knots an hour. Encouraged by this success, they are installing producer-gas engines of greater power in another vessel, from which even better results are expected. The question of equipping a battleship with a plant of this kind cannot be settled, except by a gradual increase in the size of the equipment, until it has been proved that the various difficult problems incidental to a large marine producer-gas engine have been successfully mastered. The present indications are that this will eventually be done, and when it is, the efficiency of the warship will be vastly increased. There never was a time when naval powers exhibited so much activity in the enlargement of their fleets as just now, the greater part of the appropriations being devoted to the construction of battleships of the all-big-gun type. Outside of these, new constructions are being confined to fast scouts of about 5,000 tons displacement and 25 or 26 knots speed, destroyers of from 600 to 800 tons, and submarines. The development of the last-named type has been steady, both the size and speed having been materially increased during the year. It is gratifying to realize that the United States Navy now holds the second position in fighting power. This is due to the fact that we have put most of our displacement into heavily armed battleships; and if we continue to follow the proposed plan of building two battleships a year, we shall have no difficulty in maintaining this position.

MERCHANT MARINE.

In respect of the addition of new merchant vessels of the first size and speed to the merchant marine, the past year has been less notable than its immediate predecessors; but it has been remarkable for the performances of some of the ships already afloat. Precedence is naturally taken by the two latest

transatlantic liners, the *Lusitania* and *Mauretania,* which, after the stormy experience of the winter, settled down to a steady run of record breaking across the Atlantic. The most puzzling performance of the year was that of the *Mauretania,* when, during a trip early in June, in which, because of an accident, she was run under only three out of her four propellers, she covered the longer northern route in four days twenty hours and twelve minutes, at an average speed of 24.86 knots, not only beating her own record made with four propellers, but also that of the sister ship *Lusitania*—a result which would seem to show that the boiler capacity of these vessels is not equal to that of the turbines. Later in the same month the *Lusitania,* in making a passage in four days and fifteen hours, at an average speed of 25.04 knots, earned the distinction of being the first 25-knot transatlantic liner. On a subsequent trip the last-named vessel covered 650 knots in one day, at an average speed of 25.66 knots. The fact that the *Mauretania* made her best speed with one of her high-pressure turbines out of commission afforded further evidence that the most efficient work of the steam turbine is done in the low-pressure turbines, and confirmed the judgment of those marine engineers who believe that a combination of high-pressure reciprocating engines and low-pressure turbines will give the best results. Hence great interest attaches to the performance of the 14,500-ton *Laurentic,* which was launched during the year for the transatlantic service of the White Star Line. Her motive power consists of two reciprocating engines driving two outside propellers, and a low-pressure turbine on the center line of the ship. Evidently the limit of size in ocean steamers has not yet been reached, as witness the construction which has recently been commenced at the Belfast yard, of two ships, the *Olympic* and the *Titanic,* for the White Star Line, which are said to have the enormous dimensions of 930 feet over-all length, and 60,000 tons displacement. These vessels, also, will be driven by a combination of reciprocating and turbine engines, and they are expected to show a sea speed of 21 knots an hour. There is no indication of a desire on the part of any of the

leading steamship companies to emulate the high-speed performance of the Cunard liners. The German companies seem to be satisfied with the 23¼ and 23½ knots speed of the *Kaiser Wilhelm II* and the *Cecilie,* and if they have any plans for winning back the blue ribbon of the Atlantic, nothing has been made public to that effect. The prevailing type of transatlantic liner of the future seems destined to be the combined freight and passenger steamer of moderate speed. Unfortunately, the American merchant marine remains in the moribund condition which has characterized it for many years past. In spite of the earnest support of the President, Congress failed to pass the measures which had been proposed with a view to its resuscitation. Meanwhile our merchant marine on the Pacific is being rapidly swept out of existence, and it is a fact which cannot be disputed that, were we suddenly to find ourselves engaged in a naval war, we would be terribly crippled for want of transports and colliers, to say nothing of a body of seamen from which to recruit the personnel.—"Scientific American."

THE PRESENT AND FUTURE NAVAL CONSTRUCTION.

The Admiralty are at the moment formulating a Navy program for the next financial year. There are, fortunately, many stimulating influences, and there is no room for doubt as to the duty of those responsible for the efficiency of the fighting fleet. There is universal acceptance of the dictum laid down by the First Lord of the Admiralty at the Cutlers' Feast at Sheffield last week, that "we must at any cost and on all occasions meet whatever demand the condition of foreign fleets might impose upon us." We presume, too, that Mr. McKenna realizes the fact that the "condition of foreign fleets" must unfailingly be met in anticipation. The need for this anticipatory measure has been further demonstrated by the course of international politics within the last few weeks. The grave interference with the Treaty of Berlin showed, to quote the words of the President of the Board of Trade, "how very vain it would be for a nation like ourselves to trust merely to the stipulations

of international agreements, or to the smooth phrases of ceremonious diplomacy." Again, the remarkable disclosures of the German Emperor, assuring us that in Germany the prevailing sentiment among "large sections of the middle and lower classes" is not friendly to England, should, as the French say, "nous donne sérieusement à penser." Fortunately, we have at the same time a more widely and more influentially expressed desire to remove all naval questions from the somewhat unsatisfactory atmosphere of party politics. Mr. Walter Long, a member of the Balfour Cabinet, put forward this plea, and his views were cordially reciprocated by Mr. McKenna. It is true that the party system of government creates an opposition whose primary function is to criticize; but there is often suspicion that their attitude is biased, and this in part defeats the end. It must be admitted, however, that for many years there has been a tendency to regard the Navy policy from a national rather than a party point of view; but when the question at issue has to be decided in the division lobbies, the crack of the party whip has more influence than sound judgment on the part of each member. We hope, therefore, that the Navy will be still further dissociated from party politics. There are in the House few who do not realize the importance of a powerful and efficient Navy, and thus there should always be that honest and well-informed opinion and criticism which are essential to efficient administration. In view of all these elements in the situation of the day, it becomes prudent to review the present and future of construction for the British and foreign navies, as upon this depend in large measure our naval requirements of the immediate future.

The Prime Minister said quite recently at Leeds, "Every Power in the world knows that our measure of what we require in naval strength is the measure of security, and nothing more." The crux of the question, therefore, is the progress of the ships to maintain this security, and of those building for foreign Powers to menace it. For the moment it is admitted on all hands that the position of the Navy relative to other fighting forces is satisfactory. The question is one regarding the

future; the situation must be viewed with special reference to that future. Again, there is no need to explain why such a comparison of strength may be quite properly confined to "capital" ships of the *Dreadnought* type. Following the prototype, laid down in 1905, there were ordered in 1906-7 three British ships, but not one of these was laid down until about eight months of the financial year had expired. The *Bellerophon,* the keel of which was laid on December 3, has only just completed her trials, and will not be commissioned within the two years; the *Téméraire* was laid down on January 1, 1907, and it is problematical whether she will be completed within two years and three months. The *Superb* was laid down on February 6, 1907, and although she will go on her trials in January or February next, there is little likelihood of her completion within two years and three months. In the financial year 1907-8 three more battleships were ordered. The *St. Vincent* has been launched, but although sixteen months have transpired since the building of the ship was sanctioned by Parliament, little of her armor has been put in place, and less has been done in connection with the manufacture of her turbines. The *Collingwood* is to be launched at Devonport tomorrow, nine months from the laying of the keel, and it has been admitted officially that there has been great delay here also in connection with the construction of the machinery. The third ship, the *Vanguard,* promises to be more up to time. But the important point in connection with these six batleships is that not one of them is likely to be completed within two years. The explanation may be quite acceptable: it is associated with labor disputes. But such causes of delay are so inevitable that it would be false policy to eliminate them in estimating the time necessary to complete battleships. An eighth ship of the *Dreadnought* class—the *Foudroyant*—was authorized in July last, but the keel has not yet been laid. Moreover, neither armor nor gun machinery seems to have been ordered, according to Mr. McKenna's statement at Sheffield. It follows that while we may have four *Dreadnought* battleships in commission next summer and seven in the summer of 1910, the eighth

will not fly the pennant before the spring of 1911. Some urge that the *Agamemnon* and *Lord Nelson* ought to be classed as *Dreadnoughts,* in view of their gun-power; but there is the important difference that their speed is only 18½ knots, as compared with over 21 knots, so that in tactics a squadron of high-speed ships including two *Agamemnons* would forfeit the enormous advantage it possesses in rapidity and accuracy of gun fire consequent upon the higher rate of change of range. Even admitting the *Agamemnon* and *Lord Nelson,* we have ten battleships. The new cruisers of the *Invincible* type offer confirmation of the difficulty of insuring production within two years. The time allowed for the building of these cruisers was, if we mistake not, two years and three months. All of them have passed through their steam trials, and two of them have been commissioned; but in no case was the ship put into commission within the time allowed. Here, again, a reasonable explanation is forthcoming; but the fact remains that we have not built within the time estimated, and that fact should be looked squarely in the face. It may be accepted, therefore, that possibly by the spring—more probably by the summer—of 1911 we shall have fourteen "capital" ships, including eight *Dreadnoughts* and four *Invincibles* built and building, and the *Agamemnon* and *Lord Nelson.*

What is the situation in respect to foreign navies, and particularly with respect to that nation of which their Emperor says they are not "friendly to us?" In 1907 Germany laid down four *Dreadnoughts.* Three of these have been launched at Wilhelmshaven, Bremen and Stettin, respectively; the fourth will be launched very shortly from the Germania Works at Kiel. The first two are in a fairly advanced stage, and all will certainly be completed by the summer of 1910. Orders were issued a month or so ago for three more battleships of the same class from the yards at Wilhelmshaven, Bremen and Kiel. These ships are to be completed early in 1911, and are to replace the *Oldenburg, Siegfried* and *Beowulf.* Preparations have already been made for laying down two more early in the year; one of them, it is understood, at Stettin, and the

other in a government yard. These should be completed probably in the autumn of 1911, certainly early in 1912, which allows in each case from 2¾ to 3 years for construction, as compared with two years and three months for the British ships. This is giving Britain an advantage which a full knowledge of the relative building facilities of the two countries scarcely justifies; but we desire to take the most moderate view. A cruiser comparable with our *Invincibles* was laid down a year ago at Hamburg; another has recently been ordered from the same yard. A third will be ordered early in the coming year. For a time some contended that we were not entitled in this country to reckon German ships until they were ordered, and on this plea our assumption that two battleships and a cruiser will be ordered early next year may be criticized; but as definite preparations are being made, and as the general program has been advanced rather than delayed, there is full justification for accepting the view that the German people are determined to carry out the plan in its entirety. Therefore nine ships have been laid down within two years—seven battleships and two immense cruisers—and three more will follow in a month or so. Germany will have twelve "capital" ships of the *Dreadnought* type late in 1911 or early in 1912. Italy has in an advanced stage one modern battleship; France has six, which ought to be finished by 1912; Austria has laid down one, and proposes to construct two more; America has in hand four, and Japan has four—one of them launched two years ago, another floated a year ago, and two others in progress. These facts speak for themselves. A similarly disquieting condition could be established in connection with the smaller ships.

The condition that the Admiralty at the moment should have under consideration is that Germany will have in 1912, if not earlier, twelve "capital" ships against our fourteen, including even the *Agamemnon* and *Lord Nelson*, which is stretching a point. The point to be determined now is as to how many ships we should lay down to give us unqualified superiority at the end of 1911. Germany has shown her hand. Her program has been published to the world. As to the intentions

of the Government and people there is no room for dubiety; any last lingering doubt must have been removed by the Kaiser's declaration. He may be friendly to us, but the wisest monarch is not always able to mold public opinion at will, and it would be a grave error to ignore the significance of the situation on the Continent. According to the Kaiser's narrative, it was only our naval strength which saved the world from a great European war in 1899-1900. The same conditions may arise again tomorrow, and certainly the maintenance of peace depends upon the decision of the Admiralty and of the Cabinet within the next two or three weeks. Mr. McKenna, at Sheffield, made one more protestation of the earnest desire of the Government to maintain our supremacy—"the British Navy has got to be of a strength to meet any reasonable and possible foe or combination of foes." In *Dreadnoughts* Germany in about three years will be practically equal to Britain. The German squadron of *Dreadnoughts* could easily annihilate any fleet of ships of the pre-*Dreadnought* era that we might put to sea, so that our reliance must not be placed on our older ships, however preponderating their numbers may be. It is the full realization in Germany of this point which has induced them to build *Dreadnoughts* in such large numbers. We know, too, that Germany has determined to build at least two battleships and a large cruiser each year; and as our preponderance in modern "capital" ships will no longer exist in 1912, it is of the most vital importance that the Admiralty and the Government should determine in the next Navy program to lay down such a number of ships as will at once begin the building up of such predominance in *Dreadnoughts* from 1911 onwards. When it is remembered that Germany may accelerate the rate of construction of the twelve ships under order, and will continue to order new ships in the future years as in the past, it will be agreed that five ships is the irreducible minimum for next year's program and that six is really necessary.

Now is a most opportune time for laying down these ships. An enormous amount of distress prevails in every district, and in none to a greater extent than in naval shipbuilding ports.

This justifies a concession to the unemployed. A battleship nowadays costs about £2,000,000 sterling, and almost the whole of this amount is distributed in wages. We are glad to note that this has been brought out with remarkable clearness in the daily press, because it is sometimes thought by the ill-informed that money spent on naval works is confined to ship-building districts. It is not so. No expenditure affects a greater area. There are minerals and coal to be mined, transported and converted into the requisite metals; there is the armor to make, the hull to build; there is the machinery to be manufactured by specializing firms dotted over the whole of the United Kingdom. Thus the early ordering of five or six battleships would be an incalculable benefit in utilizing idle labor. This is apart altogether from the absolute necessity of laying down the new ships. It has been computed, for instance, that in the hull and propelling machinery alone on a *Dreadnought* over 2,000 workers would be employed for a period of two years. But if we take the labor value of a battleship as nearly 1¾ millions, and assume that the average worker's wage is 32s. per week, we find that the direct contribution to labor means the employment of 10,000 men for two years. There is, moreover, the indirect gain, as these workmen circulate the money, affording employment for great armies of workers, providing food, clothing and the necessaries of life. As the President of the Local Government Board has contended, national economy requires that the work on Government and municipal undertakings should be so timed as to level up the hollows between the peaks marking commercial activity in the diagram of labor employment.

It may be urged that the repeated protestations from the members of the Government, from the Premier downwards, prove their full realization of the need for a strong Navy, and make it unnecessary for anyone to urge them to the fulfilment of their duty. Unfortunately, however, there are sounded at times notes which do not ring true, and these only tend to more seriously disturb the general unison. But there is the further fact that the national finances and the budget prospects are in

a most uncertain condition. The Chancellor of the Exchequer professes to know how the probable immense deficit and the enormous demands for social legislation are to be met, but men who have greater experience of national accounting do not take the same optimistic view, and consequently there is a fear, rightly or wrongly, that the claims of the Navy may suffer. We know that, so far, all has been well with the Navy, and we have on the Board officers of experience and of unquestionable loyalty to the Service and worthy of the confidence reposed in them. At the Lord Mayor's banquet a year ago the First Sea Lord gave reasons for the hint that we could afford to slumber quietly, feeling sure that then all was well. Now we have cause to be awake, and we await the issue. —"Engineering," Nov. 6, 1908.

NEW BRITISH WARSHIPS.

During the week the Admiralty have made good progress with the apportionment of naval work provided for in the Estimates for the financial year ending in March next; but in view of Tuesday night's debate in the House of Lords, and of indirect criticism in the House of Commons, there is no question that much dissatisfaction prevails, owing to the delay in the laying down of battleships to meet the strength in modern ships in foreign navies early in 1911. Everyone is satisfied with the unequivocal statement of the Prime Minister that we must have a fleet of capital ships equal to that of the two greatest foreign Powers, with a margin of 10 per cent. This condition, as we have pointed out in previous articles, will be met by our present building program up to the early months of 1911, but then we shall be excelled unless provision is made at an early date for adding to the number of ships now in course of construction six or seven new capital ships. The Navy program for next year is, therefore, the subject of keen interest, and Earl Cawdor, the late First Lord of the Admiralty, Lord Brassey and others experienced in naval affairs expressed dur-

ing Tuesday's debate the strong conviction that several battleships should be laid down without delay.

The two large ships provided under the current year's program have not been commenced, although suitable berths have been vacant for some time at Portsmouth and Devonport, and although their construction was authorized some months ago. The machinery for these ships has not yet been ordered, but tenders have this week been delivered at the Admiralty from several engineering firms in connection with this work. Nor has the armor or armament been put in hand, and this delay was also animadverted upon in the House of Lords on Tuesday. The ordnance firms are more than capable of fulfilling all Navy requirements, and, consequently, the official excuse made for delays in the past—that very few firms made ordnance—was beside the mark. Unless the work is given out at a reasonable time it is impossible for it to be completed at the required date, irrespective of the number of makers. Engineers know well the enormous capital involved in ordnance-manufacturing plant, and sufficient inducements have not been held out to capitalists in the past owing to the small proportion of the expensive plant maintained in full work. There seems no reason why work for the two capital ships authorized several months ago by Parliament should not have been put in hand some time ago. This applies in equal measure to the battleships to be ordered next year, and Parliament ought to insist on the work being ordered at such a date as will leave no doubt of the completion of these ships by 1911, irrespective of such inevitable emergencies as labor disputes, etc. This year's new battleship is to be of the improved *Dreadnought* type, and the cruiser of the *Invincible* class, and both will have turbine machinery, the former of 23,000 horsepower and the latter of 45,000 horsepower.

The next important ships in the year's program are six second-class cruisers of about 4,500 tons, 26,000 horsepower, and 26 knots' speed. These vessels are intended to act as scouts, and alike in their armament and radius of action they will be greatly superior to the 3,000-ton scouts launched in

1904. These vessels will cost, apart from armament, about £300,000 each, and it is a remarkable fact that the tenders of the successful tenderers varied only by 3 per cent., while the higher tenders ranged up to 20 per cent. more than the lowest. One of the ships has already been put in hand at Pembroke, and the others are to be built one each by Messrs. Vickers Sons & Maxim, Limited, of Barrow-in-Furness; the Fairfield Shipbuilding and Engineering Company, Limited, Govan, Glasgow; Messrs. John Brown & Co., Limited, Clydebank; Messrs. William Beardmore & Co., Limited, Dalmuir; and Sir W. G. Armstrong, Whitworth & Co., Limited, Newcastle-on-Tyne.

Sixteen destroyers were provided for in the new program, and all of these have now been ordered, the prices ranging from about £100,000 to £120,000. Some discussion has resulted from the fact that the Admiralty, while maintaining the displacement at about the same total (900 tons), have reduced the speed from 33 to 27 knots. At first sight this seems a change of serious import, but it is not possible to form a definite opinion regarding the speed without full knowledge, and when this is available it will probably be admitted, even by the critics, that in service in a seaway the new vessels will prove faster than the old. It should be remembered that, after experience with the light 30-knot destroyers built five years ago, the Admiralty introduced what was known as the River class, giving them a speed of 25 to 25½ knots. These vessels, launched in 1903 to 1905, were of stronger build, with a high forecastle, and were more heavily armed. They are thus able to continue in a seaway at a higher rate of speed than was possible, under the same weather conditions, with the earlier boats of from 300 to 400 tons displacement. The displacement was increased by quite 60 per cent., and almost the whole of this was absorbed by the hull, the machinery only taking a small proportion of the addition. The advent of the turbine suggested a still further advance in speed—to 33 knots; and there can be no question that these vessels, belonging to the Tribal class, have done remarkably well. The actual speeds

attained on trial ranged from 33½ to about 37 knots. This was in consequence of the adoption of oil fuel as well as of highly efficient steam turbines. The hull, however, suffered in some measure, a fact which will be better appreciated when the relation of power to total displacement is taken into consideration. In the early 30-knot vessels the power equalled 16 indicated horsepower per ton displacement. In the River class this was reduced to about 12 horsepower; in the 33-knot class it rose to 18 horsepower per ton, whereas in these new vessels there will be a reversion to near the ratio existing in the River class.

Without entering into any question of the strategical and tactical advantage of speed, particularly in these vessels, it must be accepted that speed in a seaway is at least as important as the maximum speed in smooth weather. This involves some consideration of the function of the destroyer; if the vessel is merely to destroy torpedo boats, then the weather conditions assumed in design need not be any more unfavorable than that provided for by torpedo boats. There is, however, a tacit understanding that the destroyer will be used in certain circumstances for scouting duty, or for dispatch work, when the maintenance of a high speed under adverse sea conditions will be of enormous advantage. It would seem, therefore, that what ought to be aimed at in these craft, as well as in all warships, is a thoroughly reliable normal speed, with provision for moderately safe overloading of the machinery in extreme emergency. Fortunately, the steam turbine admits of a far higher degree of overloading than the piston engine, and without forfeiting any measure of steam efficiency. That being so, the design of torpedo-boat destroyers should be so conceived as to give satisfactory normal speed, with mechanical facilities to deal with abnormal overloads, even if they involve risks. In other words, the steam-generating plant should have a fairly large margin, and the steam pipes should be of considerably greater capacity than normal conditions demand. This latter point is of considerable importance, and in some of the recent turbine-driven ships difficulties have been experienced because

of insufficient area of steam leads. In the case of a vessel having a margin of heating surface, and with large pipes, there would be little difficulty in adding to the speed of the destroyer in the event of emergency justifying great risk by the engineer. We therefore hope that, although the trial-trip speed of these new vessels is to be 27 knots, they will have such reserve of power to enable them to excel under the courage of their engineering and executive officers. It is said that in these vessels provision has not so far been made for oil fuel, but there seems no reason why this should not be added by the dockyard authorities after the vessels have been delivered. Such an arrangement would enable the boilers to be worked normally with coal, and with liquid fuel when conditions justified it.

The sixteen destroyers we have referred to are to be built—three each by Messrs. John Brown & Co., Limited; the Fairfield Shipbuilding and Engineering Company, Limited; and Messrs. Cammell, Laird & Co., Limited; two by Messrs. J. S. White & Co., of Cowes; and one each by Messrs. William Denny & Bros., Dumbarton; Messrs. R. and W. Hawthorn, Leslie & Co., Limited, of Newcastle-on-Tyne; the London and Glasgow Company, Limited, Glasgow; the Thames Iron Works and Shipbuilding Company, Limited; and Messrs. J. I. Thornycroft & Co., Limited, Southampton.

The Navy Estimates provide for a number of submarine boats, but no information is given as to the progress made in connection with these, and as the Navy Estimates do not indicate even the number to be built, a question ought to be put in Parliament as to this important matter, especially in view of the earnestness with which other Powers are proceeding with the building of this type of craft. We have either in course of construction or completed only 72 vessels; while France has 97; Russia, 36; the United States, 27; Japan, 13; Italy, 13; Germany, 8; and Austria-Hungary, 6. Thus it will be seen that we have a considerable deficiency in this new type of vessel, which admittedly has enormous potentialities. It would be well to have an official announcement at an early date regarding the intentions of the Admiralty.—"Engineering," Nov. 27, 1908.

THE STATUS OF SOUTH AMERICAN NAVIES.

The South American States, particularly the Republics of Chili and Argentina, were at one time frequent purchasers of war ships in this country, but during the last ten years, with the exception of the huge order for Brazil now in progress of construction, and two small cruisers for Peru, little or nothing has been done, and the relative status of the fleets of the two first-named countries is the same as it was in 1902. About 1898, when relations were strained between Chili and Argentina, both countries possessed several up-to-date vessels recently acquired—either from Elswick or from Ansaldo-Armstrong in Italy—one or two being remarkable examples at that date of the combination of power and speed. Chili purchased a couple of "stock" destroyers and a cruiser in England in 1902, but since that time neither Power has increased its fleet. The general depression in the shipbuilding trade that has existed for the last two years has caused some attention to be given to the recent vote of £14,000,000 for naval purposes by the Senate at Buenos Ayres, and, taken in conjunction with the enormous changes in naval designs since previous orders were placed, and the overwhelming superiority that Brazil will possess by the end of this year, it is impossible to avoid the feeling that not only will large orders for new war material be placed at an early date, but that there will also be a well-advised scrapping of the older existing vessels. On the far side of the equator and in the South Atlantic any vessel with a gun mounted on it has hitherto possessed a totally different relative value from what it might have in Europe, but the principles of naval warfare, and the effect of well-directed gunfire, remain the same, whether the combatants be Balmacedists, Japanese or British. The wholesale scrapping of warships in the Royal Navy was a far-sighted, and, as it has proved, a successful financial move, but it was made possible only by our overwhelming superiority in first-class vessels, and the relative value of the ships then disposed of had been largely discounted by the enormous improvements in the design of later vessels. From the military point of view, as long as the balance of

power in South America remained undisturbed, less, perhaps, by stagnation in military ardor than by the financial stringency that existed, for either Power to get rid of warships, even eighteen or twenty years old, would have been absurd, but there is no doubt that many of the older vessels would be quite useless for encounters with modern vessels of even small size.

Few countries work their vessels to the extent that the British ships are worked, and, except Germany, none take the same trouble in refitting them. But reports both from naval and private sources indicate that the Chilian vessels at least have been taken care of; several have been reboilered, and one or two rearmed; still there is no more reason for ships built in 1890 or 1892 to remain efficient in the Pacific than if they were in the Channel. Most of the British 30-knotters of 1895-6 are about worn out, and it is hard to believe that the *Orella, Santa Fé* or *Hyatt* types of destroyer and torpedo boat are much better off. Such ships as the *Belgrano* class of four vessels in the Argentine Navy should still be serviceable vessels, while the *Esmeralda* and *O'Higgins* were so far in advance of their contemporaries in all countries that with the upkeep that they have enjoyed they remain formidable opponents. The *Chacabuco,* one of the latest small cruisers acquired by Chili, is a sister ship to the *Takasago,* sunk in the war in the Far East while doing useful work for the Japanese. But to the numerous older vessels in each Navy, many of them famous for the part they have played in various wars and revolutions, it is impossible to assign any value beyond that of being just as good as their opposite numbers in a possible hostile fleet; among these must be included nearly all the ships classed as genuine battleships, for, with these few exceptions, South American States content themselves with cruisers.

Only semi-official inquiries have so far been made for new Chilian work, but the battleship that is suggested for Argentina is at least of European proportions and of tremendous offensive power. The construction of the Brazilian battleships of the *Minas Geraes* type has rendered ships of equal dimensions almost necessary if any equality of power is to be maintained,

and such ships possess so great a superiority over anything now in South American waters that to continue to maintain such vessels as the *Almirante Cochrane, Capitan Pratt* or *Libertad* type is a poor policy financially. The new Brazilian scouts *Bahia* and *Riogrande,* of 26½ knots speed, are the modern development of the *25 de Mayo* and *Nueve de Julio* class of light protected cruiser that emanated in such numbers from Elswick in the early nineties. Chili and Argentina possess seven or eight between them, all of which were remarkably fast on trial, but have since fallen off somewhat. All the British cruisers of that date have long since been scrapped or devoted to such purposes as mine-laying, mothering submarine boats, or similar duties not involving offensive attacks on hostile vessels. At present few of the Chilian and Argentine boats, except possibly the *Buenos Ayres,* could hope to escape from the Brazilian battleships. The readjustment of naval equality between these States is now occupying the attention of statesmen, naval constructors and financiers in many parts of the world, and to this country, which has supplied the majority of the ships in South American navies, the solution is a matter of no little interest.

It has repeatedly been stated that the Brazilian ships were never intended for Brazil, that they would be transferred to some other flag before completion; but the improbability of such a step increases as time passes. Two of the destroyers have already sailed, and the contract with the Brazilian Government also embodies the reconstruction of the Naval Arsenal at Rio de Janeiro. In addition to which the purchase by a naval Power of vessels designed for another country has seldom proved satisfactory, as many well-known cases go to show. The acquisition of the old *Neptune* and *Swiftsure* from Turkey, of the *Albany* and *New Orleans* by the United States from Brazil, and the Japanese purchase of the *Nishin* and *Kasuga* from Argentina, and the *Idzumi* from Chili, were all steps forced by urgent necessity, and the ships did not prove ultimately suitable, however useful, at the moment. Although

they carry a huge armament, we do not think that the *Minas Geraes* and *San Paulo* are up to British requirements. They are not fleet ships in the naval sense; their protection is much less than in the case of the *Dreadnoughts*, and while, doubtless, possessing many valuable features, they are not suitable for European conditions.

The other States in South America hardly possess or require navies. Peru recently acquired two very fast little scout cruisers from Vickers, and Ecuador took over the *Ministro Zenteno* and *Almirante Simpson* from Chili. Uruguay lately purchased from Italy the Elswick cruiser *Dogali*, built in 1888, but beyond these minor movements nothing has occurred. The practical certainty of the Brazilian ships leaving England before the end of the year is a political factor of considerable importance in South America. Either Chili and the Argentine must commence new programs at an early date, or the equality of precedence in the affairs of that continent, hitherto held in the balance between them, must be surrendered in favor of Brazil. The Argentine naval budget is by far the largest ever put forward. Chili was inquiring for two large ships just before the Valparaiso earthquake, but the enormous losses then incurred prevented further negotiations for a time. We cannot help thinking that two countries which have had their fleets supplied from this country will shortly assist in relieving the existing depression in shipbuilding, and that the reconstruction of dockyards necessary in South America will also figure in the expected revival of trade in those countries themselves. Ships are useless without adequate accommodation, and a large feature of the projected programs must be the modification of existing drydocks, the largest one at present in Brazil being the Lloyd Brazileiro dock at Sande Point, at Rio, which is 484 feet long by 70 feet wide. Montevideo possesses one 490 feet by 85 feet, Talcahuano one 633 feet by 82 feet; but the two big docks at Buenos Ayres are only 65 feet wide. The price of Admiralty is apt to be high, and Chili is fortunate in having a dock already available.—"The Engineer."

STEAMSHIP SPEEDS AND SEAGOING ENGINEERS.

The armored cruiser *Invincible* has attained on trial a higher mean speed than has ever been reached with seagoing ships, and the moment is therefore particularly opportune to consider the advance in speeds and its relation to the qualifications and status of seagoing engineers. The *Invincible,* on her full-power trials, attained a mean of 26.6 knots over a deep-sea measured course, and the two sister ships are regarded as capable of maintaining this rate. They have different propellers, the Admiralty desiring comparative data in order to further advance their knowledge of screw efficiency. Thus any little difference in speed attained on trial will disappear by adopting that form of propeller which proves the most satisfactory. The turbines, too, proved very economical, even at the lower powers. Further tests are to be made, but the long-distance steaming of the *Indomitable* and *Inflexible* support the results of the *Invincible's* trials, and every one associated with the three vessels may be cordially felicitated on the result, and particularly on the short time in which these powerful and fast vessels have been built.

The high speed attained by the three vessels is but one more step—although a large one—in the steady advance made in navy engineering within recent years. It follows that a greater demand is made on the personnel in the machinery room, but the extent of the requisite higher qualities, alike in engineering knowledge and resourceful courage, is not fully appreciated. This can best be done by a glance backward, which few have time or opportunity to take. In 1893 there was not a single armored ship, built or building, with a speed exceeding 19 knots. Of cruisers officially classified as protected or unarmored ships there were only four which exceeded 21 knots speed—the *Blake* and *Blenheim,* whose full speed was unreliable because of the danger of pressing the boilers, and the *Powerful* and *Terrible,* then in course of construction. Between 20 and 21 knots there were thirty cruisers, and between 19 and 20 knots fifty-two cruisers. It will thus be seen that

21 knots was practically the maximum speed in the Navy fifteen years ago. Now there are twenty-six armored ships exceeding 23 knots, in addition to sixteen unarmored ships, mostly scouts. Indeed, practically every battleship built this decade has been of over 19 knots; and every cruiser, whether armored or dependent for protection on horizontal armor, has exceeded 23 knots. The exact figures are—

Knots.	Armored warships.		Unarmored warships.	
	1893.	1908.	1893.	1908.
18 to 19	12	26	11	1
19 to 20	...	9	52	32
20 to 21	...	4	30	35
21 to 22	...	8	4	5
22 to 23	...	7	...	5
23 to 24	...	20	...	1
24 to 25	...	3	...	5
25 and over	...	3	...	10

As regards destroyers the same progress has also been made. The boats of fifteen years ago were of 27 knots speed; there are now in the Service many of over 33 knots, and one with a legend speed of 36 knots is now running her trials. It is true that in the case of the vessels of this class recently ordered there is a reversion to 27 knots speed, but the designs and conditions are so different that there is no comparison; indeed, it would be more accurate to classify the new vessels as torpedo-destroying cruisers. In the British merchant service we have almost equal progress in respect of speed. In 1893 there were twenty-five vessels of between 18 and 19 knots, and nineteen vessels exceeded this rate. Now there are fifty-four vessels of between 18 and 19 knots, twenty-seven between 19 and 20 knots, and fifty-seven exceeding 20 knots. In the Navy there are 106. Not only do these figures show greater progress in the Navy, but full use is made of the higher speeds.

Fifteen years ago the full speed, even on trial, had only to be maintained by warships for four hours. Now the trial is of eight hours' duration. But, what is more significant, the warship squadrons steam now at a greater speed in ordinary

cruising, and are frequently called upon to make prolonged runs at about full speed. This practice is most commendable, as the advantage to the personnel, alike in the engine room and on the navigating bridge, is great, adding enormously to experience in navigation and maneuvering in the one case, and in continuous steaming conditions and requirements in the other. The endurance of naval machinery is tested to the fullest extent, and there is greater certainty that the high speeds aimed at in design will be available in war. Another point which shows that a greater advance has been made in the Navy is the fact that of the merchant ships exceeding 20 knots only twelve are for long-distance voyages—principally for Atlantic trading—the remainder being for river and Channel service, where the period of continuous steaming is not great.

These facts—higher speed and its utilization in maneuvers—justify some reflection as to the greater technical knowledge, practical experience, administrative ability and mental and physical energy required by the seagoing engineer in the naval and mercantile fleet. There is no desire here to depreciate the services of the men who in the old days established, by watchfulness and care, the reliability and economy of the marine engine. Indeed, many early engineers by their inventive ingenuity assisted towards the development of the main propelling engines and of the auxiliaries, increasing both the economy and the steady running of the machinery of warships and merchantmen. Thus they helped to bring about the complete supersession of sails. The advance in speed, especially in warships, has involved a limitation of weight per unit of power, a lowering of the factor of safety, and a diminution of the bearing surfaces, so that increased vigilance is necessary in order to obviate breakdowns, apart altogether from the difficulty of attaining to the high standard of efficiency now called for. The effort of the designer towards higher speeds has also involved increased intricacy, and consequently a higher degree of intelligence in the engine room. The multiplication of machines, too, requires fuller knowledge in supervision, especially after a long run, so as to ensure that everything will be maintained at

"concert pitch." When a merchant ship arrives in port, overhauling work is done by the shore staff; whereas in the Navy full encouragement is given to the engineer officers of the ship to undertake repairing work which is not extensive. This is well, since there is greater desire and effort to keep the machinery in a high state of efficiency and reliability, and to obviate as far as possible the necessity for extensive overhauls.

This suggestion of the comparative conditions prevailing in the Navy and merchant services may seem to do some injustice to the officers of the mercantile marine, but there is no intention to disparage their splendid services. Indeed, in no profession is it possible to find men of higher probity and wider experience; the point, however, is that the Navy service calls for fuller knowledge and greater experience, although, perhaps, not greater vigilance. The engineer in the merchant ship has a freer hand; without this it is doubtful if absolute discipline could be maintained in some merchant ships. It is true that there is a larger proportion of scalliwags among the stokers of a merchant ship than in the Navy; but here, again, the requirements of the fighting fleet demand a much higher degree of discipline, as it is second cousin to that historic courage absolutely necessary in the hour of peril, alike in the engine room and the gun turret.

The increase in warship speeds constitutes a primary strategic and tactical advantage. There are some who go the length of saying that battles will be won by speed; but without attempting to elevate it to such exclusive importance, it will be accepted that the engineer and his work are of great fighting value, and his recognition should be in direct proportion. He has directly under him about 40 per cent. of the full complement of the ship. It may be estimated that the engine-room complement of the fastest cruisers totals 320, the engineer-commander having under him three engineer-lieutenants and three assistant engineers, with a large staff of engine-room artificers and chief stokers. He has an enormous variety of machinery to look after, about sixty separate engines, excluding the turbines, and also a great number of boilers. In

other words, he may have machinery under his control of a value of £450,000. This is apart altogether from the influence of his work on the winning of battles. Can anyone justify a system which refuses administrative power to an officer upon whose ability for organization and administration so much depends? In commerce and industry the idea would never be thought of, and it is not therefore surprising that the great technical institutions of the country from time to time make a strong protest against the continued refusal of the Admiralty to grant executive rank to the engineering officers of the Service. The Northeast Coast Institution of Shipbuilders and Engineers has been prominent in urging this most desirable naval reform, and Mr. Summers Hunter, the president, in his inaugural address on Friday last, returned to the subject. His position as head of a large marine-engine construction company, lends influence to his criticism of the situation. He pointed out that the Admiralty recognized that the duties of the engineering officers are of a combatant nature, "by their decision that the engineers under the new scheme, and who are now mere boys, are to be military officers, and rightly so, as they are an indispensable part of a fighting organization, and as such should have the recognized military status and internal control over the department. The officer who administers his department wisely under the present conditions, when he has nothing to rely on, save his own personal influence over his men, may be trusted not to abuse authority when he is given power to exercise it." It is difficult, if not illogical, to contend that existing engineers should be denied the rights conceded as essential to the future officer of the engine room.

The very qualities which have ensured such a high degree of reliability in the engineering department of the Service, notwithstanding the increased responsibility involved by higher speeds, are exactly those which should justify the Admiralty in conferring executive power and rank on the officers. The engineer officers have proved themselves educated men, possessing the power to reason quickly and to decide promptly when emergency arises, in addition to having an intimate and

accurate knowledge of the complete construction of each part of the intricate mechanism under their control. At the same time they have established reputations for maintaining order amongst the most difficult class in the Service. Moreover, we are certain that the nature of the reports made by the officers, and the assistance they have rendered to the captain, further support our contention. Apart altogether from the personal question that the reward should follow the event, and that the engineer officer should obtain official recognition for work he now does, there is the important national question that the efficiency of the Service calls for the reform. Everyone knows that, unless there is immediate power to punish disobedience, discipline is weakened by the issuing of orders unacceptable to the men. There is an inborn spirit of deviltry in almost every Englishman which induces him to jibe at the orders given by a subservient "master." In the dormitory of the school no monitor, however high his moral character, could maintain order if he did not resort once in a while to the exercise of the "manly art." In the workshop the foreman could never maintain the standard of work if he had not the power of dismissing the recalcitrant. It is not enough to urge that the present-day naval engineer can appeal to someone on deck, who may or may not sympathize with his appeal. The lack of full technical knowledge of the offense on the part of the captain or commander involves explanation by the engineer, which is subversive of his authority. Punishment, too, should follow immediately after the act. If there are lapses during an action, disaster will follow unless the engineer break through all rules and exercises authority. From all points of view, therefore, it is imperative in the interests of the Service that this reform should be carried through, and we are glad to know from Mr. Summers Hunter that there is probability of fuller pressure being brought to bear on the Admiralty by the combined action of the technical institutions. We do not think the need is so much for awakening conviction on the part of the Board as for overcoming the prejudice of many existing executive officers of the Service, but we hope, with Mr. Hunter,

that Sir John Fisher will "crown his life's work by solving this truly national question."

There is one further point to which reference should be made, especially as it is urged as a reason for not granting executive authority and rank to the engineers. It is contended that in a few years, as a result of the new system of training and entry, all engineers will have executive rank. But is the Board of Admiralty justified in delaying admittedly necessary reforms in the prospect of a problematical success? There is room for doubt as to whether the coming officers who elect to be engineers will have the required knowledge and experience. If the Navy is to be adequately supervised and controlled, the authorities at Whitehall and at the dockyards must have the technical assistance of engineer officers who are thoroughly conversant, from practical experience, with the requirements and practical working of ships of war, and this can only be acquired after years of service at sea. Their Lordships seem impressed with this idea, because nearly all the highly trained technical officers at the Admiralty are required to go to sea after every term of two or three years at Whitehall, in order that they may gain practical experience of innovations and changes in seagoing conditions. It is doubtful if in the end the new system will give us such highly trained engineer officers. Some even question whether under the new conditions we shall have an adequacy of officers for ordinary service. The students now at Osborne show a predilection for engineering, even during their leisure, and it is therefore assumed that the engineering branch will be preferred by many youths. A knowledge of human nature, however slight, suggests caution in such assumption. Give an average lad a lathe and a piece of metal or wood, and there are few seductions in the world which will take him away from the lathe. Healthy boys in their leisure must be making something—or mischief. When they grow up do they show the same desire to play at mechanics? Moreover, financial considerations must influence the choice. The commander on the bridge will have advantages. He has, to begin with, even if only a lieutenant, 3s. 9d. per day command money, and navi-

gating allowance has been known to run up, even in small ships, to something equal to £120 a year—a nice plum, for the absence of which even the discomforts and rigor of service in the engine room will not compensate any officer of equal rank. It is conceivable in the case, for instance, of a destroyer, that the officer on the bridge and in the engine room would be of equal rank, but with very different emolument and social conditions. The temptation will be to have an officer of less rank in the engine room, which would mean a serious lapse from present efficiency. No ships require greater engineering skill and experience than the destroyer—they are now two-and-a-half-stripe engine rooms—no vessels are of greater potentialities, and any practice which would weaken their efficiency must be condemned.

We are therefore faced with the probability that, even if the present system of training is satisfactory—which Mr. Hunter doubts—the supply of engineer officers may be deficient, particularly in the earlier stages. It would therefore be well for the Board of Admiralty to ignore the prejudice of the officers afloat, and to make that reform which is necessary for the efficiency of the Service. By reason of the higher speed achieved in the later ships there is need for greater technical skill and administrative ability. The change is necessary also because in the earlier stages of the new system officers holding executive rank may occupy places subordinate to the existing engineer officers without executive authority. It is essential, too, to give the engineer executive authority, so that punishment for offenses may be direct and immediate, and in order that the engineer personnel may realize that they do not occupy a position subsidiary to the officers and men on deck duty. The only argument against the change is that there cannot be two kings in Judea. This, however, is outside the question. The captain is supreme at present; the commander only carries out his orders. Were power given to the engineer officer in his department corresponding to that exercised by the commander, all would be well. Such executive power, too, must carry with it the rank and its distinguishing mark, because in 1861, when

the curl was first introduced, it was an indication of the possession of authority; otherwise, it should be entirely wiped out.—"Engineering," Nov. 13, 1908.

THE FUTURE OF NAVAL ENGINEERING.

The most serious warning yet given to the Admiralty on the subject of the training of engineers comes from the Engineer-in-Chief of the United States Navy. It is not addressed to My Lords at Whitehall, nor is the British engineer referred to even inferentially; but that does not affect either the directness or the seriousness of the warning. We adopted, with some modification, the United States idea of training all officers on the same lines, and of making, to a certain degree, all officers available for duty alternatively on the navigating bridge, engine platform, gun turret or torpedo room. The United States system has failed in the most vital respect; and the annual report to the Secretary of the Navy by the Engineer-in-Chief in proclaiming that "engineering in the Navy must fail" supports the contention so influentially urged in this country that the future of engineering in the British Navy calls for immediate and unprejudiced consideration.

The state of the case at Washington is reflected by the following sentences from the official report just issued. "It is greatly to be deplored that the important and satisfactory work of the Bureau's school for instruction in engineering had to be discontinued for want of officers to be instructed. No new officers have been booked during the past year, and the very satisfactory organization, which had been almost perfected during its three years of existence, has been broken up." This is exactly what was expected; this is what is feared in the British service. It was in 1899 that Congress passed the Act amalgamating the line and engineering corps, and now there is no flow of officers to take up engineering work exclusively, or to specialize in it. Every officer aims at the command of a fleet; that is but human nature. It will be the same with the

young cadets now at Osborne College. The youth may enjoy working with a spanner, but he enjoys still more the dreams of the anticipatory glories of the Admiral's gilded state. The choice between the bridge and engine room is not influenced only by the superiority of the ultimate post which is the ambition of all officers. There are seductive advantages in the military officer's preliminary career; he has less arduous work, higher emoluments, greater social recognition. At sea the engineer's work is always trying, and in port there are, as often as not, overhauls to be undertaken. The pay may be nominally equal, but there is no equivalent to the command or navigation money, which greatly augments the military officer's emoluments. Nor is the engineer's ultimate reward heroic; it is probably no better than an engineer-manager's post in the dockyard under the dominance of a military officer who may have started his career at the same time. Under these circumstances it is difficult to understand why, of his own volition, any youth should adopt the more prosaic and arduous career. Only a strong love for engineering can overbalance the attractions of the military rank, and, although there will always be such preference, the relative number of cadets exercising it must be small. The Engineer-in-Chief of the United States Navy suggests that there are such youths in the American service, but even there they do not assert their love for the engineering career, and thus the chief is faced with a serious deficiency in officers to undertake the more responsible duties connected with the building up of the fleet.

We have time and again pointed to the inadequacy of the new British system of training to provide officers with that specialized knowledge and intimate acquaintance with engineering practice necessary for the design and supervision of new machinery for the service. The chief of the United States Engineering Bureau, Engineer-in-Chief John K. Barton, corroborates all that we have said. Not only has the flow of line officers for service in the constructive department ceased, but there seems to be a break in the continuity of association between the officers afloat and the constructive bureau. Not-

withstanding the enormous amount of new construction in progress, involving, as it does, inspection of material, supervision of the construction of new machinery, and, of course, careful experimental and design work, there are at the present time only six line officers engaged in such work in addition to the thirty-four for engineering duty only. These latter belong to the old régime, and their numbers are quite inadequate. Some of them have to take up two or more districts. Moreover, when any are off leave through illness, "there is a decided falling off in the discipline and conduct of work during the enforced absence of the head," because there is no skilled successor to take up and continue properly the thread of the work. It is further pointed out that "the condition is rapidly becoming worse, and the Bureau is now seriously handicapped in its work by the lack of officers for engineering duty, and also by the lack of experience of some of the officers who have been so assigned."

Engineer-in-Chief Barton tries to arouse the Secretary of the Navy to the gravity of the situation by reviewing the character of the work done by the Bureau, and points to the advantage of line officers being trained to this work. It is only the non-professional administrator who requires this point to be elaborated; and in following the distinguished American officer in the consideration of this part of the subject, we do so in the hope of influencing the non-professional officers at the Admiralty rather than of convincing engineers. There is no better way of studying the qualities of metals than in watching their manufacture and in testing their strength at the maker's works, and as all questions of design and endurance involve knowledge of metals, it will be seen how much value may be derived during the period of service in inspecting materials. It is equally important that the officers so engaged should have had experience of the stresses to which such metal is subjected in engine running. So that here, as throughout the whole course of engineering training, there must be intimate interlacing of personal experience in the several departments concerned with mechanical efficiency. In fact, "the prime requisite for the successful

engineer is to know the qualities of the materials he is to use, whether those materials are to be used in ships, guns, armor or machinery. It is equally important that the line officer—the man who is to manage the finished product—should know the capabilities and the limitations of his materials."

Even more important is the necessity for line officers supervising the work of constructing the machinery, of assembling it, and of erecting it on board. This has been fully recognized by the Admiralty in the past: the practice has been to send to the contractors' works the officers appointed as engineers to the ships. They are then thoroughly conversant, not only with the arrangement of the machinery, but with the quality of the work, and as the first few months in the working of the machinery brings to light most of the defects, the engineer is well able to overcome the difficulties, because of his intimate knowledge. In the process of "shaking down" the mass of information gained in the construction of machinery is invaluable. The dearth of engineering officers in the American service has had serious results, as the report states that there is not a single young line officer on duty in contractors' works in connection with machinery, "although the field is one of the best for instruction and development." Such a condition in the British service would almost be disastrous to fleet efficiency.

Equally important is the designing department of the Bureau. In America "there are now only two line officers on duty in the Bureau other than those for engineering duty only, and from force of circumstances one of these is engaged in work other than that connected with design." There is no department where the flow of line officers should be more constant and more regular. The work of design ought to be continuously influenced by experience from the ships; and, similarly, officers while on the starting platform should direct their thoughts along the lines of their mental attitude at the designing board. There should be action and reaction, as in a turbine, one set of brain cells serving to guide the other set which is responsible for effective work. As Engineer Barton says, "It is, and always has been, the opinion of this Bureau

that the greatest efficiency results when the officers who design our machinery are also the ones who superintend its production on shore, and later its operation at sea, for thus only can they acquire that familiarity with the needs of the service which suggests at once the things to avoid as well as those to adopt." In the past there has been such intimacy in the British service. The designing department is reinforced almost continuously by the appointment of officers from ships, and, except in cases of extraordinary adaptability to special work, no officer continues at the Admiralty long enough to lose interest in work afloat. In this way, too, it is easy to discover the man of mechanical genius. Thus the advancement of officers of great engineering knowledge has resulted in the undoubted improvement of the machinery of the British Navy. With the new system the danger is that the young officers will not be able to sufficiently concentrate their attention on any one department of study—that they will in the end know a little of everything, but will be unable to take their place in the higher branches of mechanical engineering.

The Engineer-in-Chief of the United States Navy in seeking for a remedy urges that "it is imperative that permanent assignment of officers to engineering duty shall be made after a certain length of service." Presumably they would then be young enough to enter upon a practical engineering course without having to unlearn idiosyncracies developed in their general discursive training. The reason for suggesting this idea is doubtless because "the plan to accomplish this is simple, will cost no money, and requires little legislation." But radical failures need radical remedies. Would it not be immensely better for the Fleet to revert to the old practice of entering engineer officers so that their training might begin at the most impressionable period of life, and thus enable them to acquire that fundamental knowledge essential to the higher scientific training necessary for specialization?

There must, however, be this difference, that the engineer officer shall be made co-equal in rank and status with the military officer. There is no need once more to enforce the

great advance in importance of engineering in naval ships and naval warfare. This has been done time and again. It has been proved, too, that it is almost impossible for the average intellect to acquire adequate knowledge of more than one branch of science. Moreover, the American experience has clearly demonstrated that, with the more seductive advantages appertaining to the military officer, there is apt to be little preference for engine-room work. The only remedy, therefore, is to revert to the reasonable practice of producing the naval engineer direct from the raw material, instead of converting a military officer, whose training is in some respects inimical to mechanics, into an engineer after he has passed the plastic state of mental development. It seems almost as if the only justification for the remarkable attempt to unify two separate and distinct entities is the attitude of the military officers toward the engineer. If the existing engineer were granted military rank and status, the whole problem would be solved, because the engineering system, as it at present exists, cannot be improved, so far as may be judged by the matériel of the fleet; nor can the efficiency or loyalty of engineering officers be surpassed. On the other hand, without some different system to that now in operation, "engineering in the Navy," to quote Engineer-in-Chief Barton, "must fail, and any deficiency there means as much to the efficiency of the fleet as failure in guns or torpedoes."—"Engineering."

ENGINEERS IN THE UNITED STATES NAVY.

Several years have elapsed since a radical change was made in the régime of the United States Navy, very largely as a result of the advice given by Admiral Melville when chief of the Bureau of Steam Engineering. Whereas previously engineers were specially educated to be engineers and nothing else, the new system aimed at making every officer in the Navy equally competent to fill any and every position. Under this system there was little or no difference in the training which

the executive or "military" officer underwent and that which was supposed to produce men fit to take charge of the engine and boiler rooms of a warship. It will simplify what follows if we say here that the executive, or "military," or "deck" branch of the Service is known in the United States Navy as "the line." Sufficient time has now passed to enable a good idea to be formed of the success or failure of a scheme which in theory had much to recommend it—so much, indeed, that without following it in all details, our own system of training officers has been modeled on it, with some more or less important differences no doubt. The theory of the advocates of the plan at the other side of the Atlantic was that young Americans had such a love of mechanism and such a contempt for social questions, which, unfortunately, have not yet been dissociated from machinery, that the cadets would rush to the engine rooms, and the difficulty would be to provide not engineers, but line men. At the time it was pointed out, however, that this was extremely doubtful; because, in the first place, deck duties are in every way more pleasant than those of the engine room, and, in the second place, that there are no officers in the world who are more ruled by caste than those of the United States Navy.

We learn from the annual report to the Secretary of the Navy by Mr. John K. Barton, Chief of the Bureau of Steam Engineering, that the worst anticipations have been fulfilled; and that unless strong measures are taken to compel cadets to take the engineering course, there will soon be no engineers in the United States Navy. A good deal is heard about the deficiencies of the British Navy personnel, but we are happy to say that so far as manning our engine rooms is concerned we are incomparably better off than the United States. Mr. Barton says that it is much to be deplored that the important and satisfactory work of the Bureau's school has had to be discontinued "for want of officers to be instructed." Although the number of officers was always too small, it was "infinitely better to instruct these few than none at all." The report then goes on to deal with the various departments which are suffer-

ing for lack of engineer officers. Among these come first the navy yards. "In important yards, with numbers of vessels under repair, the head of the department is without a single commissioned assistant." At the shipbuilding yards the conditions are still worse, "not a single young line officer being on duty there in connection with machinery." It is pointed out that the number and variety of materials used in the Navy is constantly increasing, rendering the work of inspection and selection daily more onerous. But the number of officer inspectors is continuously and steadily decreasing. Again, in the drawing offices of the Bureau itself the staff is entirely deficient; there are now only two line officers on duty in the place. Mr. Barton holds—and very properly holds—that the best results can only be obtained when the man who is subsequently to be in charge of machinery afloat sees it made on shore. It would be wearisome to go into further detail concerning the shortcomings which Mr. Barton regards with regret and alarm. It is more to the purpose to consider to what the failure of a system so full of promise is due, and the nature of the proposed remedies.

Congress has interfered at various times at the behest of men who, presumably, understood what they were talking about; but from the first there were, as we have said, protests. It was strongly maintained that, no matter what theory might say, it would be found absolutely necessary to keep the two branches—that is to say, the line and the engineers—distinct. As far back as 1899 the then Assistant Secretary to the Navy Board wrote: "The building of engines, like the building of guns or torpedoes, must be done by special officers selected or detailed for the purpose." After various modifications we come down to 1906, when the "Personnel Board," of which the present Assistant Secretary of the Navy was President, after much consideration, reported: "The Board, while in favor of the amalgamation of the line and former Engineer Corps, as provided by the present personnel law, in a general sense, desires to express the opinion that experience shows that some specialization for the design and inspection of machinery should be

created." We gather from Mr. Barton's report that the present dearth of engineers is in part at least due to the lack of line officers. The authorities regard engineering of secondary importance, and keep all the young men—nothing loth it would seem—for the deck instead of the engine room and the workshop. Mr. Barton insists that this practice must be abandoned, and he asks for that to be done which is in effect an abandonment of the essential feature of the scheme. In the hearing before the Naval Committee, the then Assistant Secretary to the Navy, said: "My own view is this: That we should, within the Department, by detail, directly reverse the policy that has for some time obtained there, of having every man in turn do every duty, the fact that he has performed the duty being considered a reason why he should never perform it again; and, on the contrary, we should, as far as we can, differentiate men after they have passed through the first eight or ten years." Mr. Barton concludes his report with the following words: "It is this differentiation that the Bureau earnestly recommends for the consideration of the Department. The plan to accomplish this is simple, will cost no money, and requires legislation only so far as to amend the personnel Act as follows: Provided, that the provisions of Sec. 5 of the Act of March 3d, 1899, shall apply to such line officers as may be assigned to permanent engineering duty by the Secretary of the Navy. A number of officers have shown marked aptitude for engineering duty and are now ready and willing to be assigned to engineering duty only, if the opportunity is given them under the above-mentioned conditions. Without such a system, engineering in the Navy must fail, and any deficiency there means as much to the efficiency of the fleet as failure in guns or torpedoes."

The truth seems to be that, leaving all social questions on one side, it appears to be physically as well as mentally impossible to collect a body of men who shall be at once eminently fit for the deck and the engine room. The duties to be performed, the lines of mental occupation, the particular capacities and qualifications required are so different that it is certain that

only a limited number of men can ever rise beyond a very insufficient mediocrity in both positions—that is to say, a good line officer can scarcely be a good marine engineer. It is probably yet more unlikely that a good marine engineer can ever make a thoroughly efficient line officer. There is a great deal to be said in favor of a single education up to a certain point; beyond that it is better that specialization should take place. The difficulty in the United States seems to be that specialization in engineering is unpopular both with the men and the Navy Board. Mr. Barton, if he had his way, would compel men to come into the engine room. Is it not possible that there is a better method? Might it not be possible by some effort to make engineering popular in the United States Navy? Or are we to believe that the Service as a whole is so unpopular that men are perforce kept out of the engine room because there are not many enough for the deck? That is the conclusion at which Mr. Barton compels us to arrive.—"The Engineer."

THE STATUS OF THE NAVAL ENGINEER.

The president referred at some length to the status of the naval engineer, pointing out that the members of the institution cannot let the matter drop until certain defects in the present system are remedied.

"Our first consideration is efficiency, and we have repeatedly given our definite opinion that efficiency is now reduced by the fact that the engineering branch is now classified by regulation as distinct from the military branch. This places the officers in a position of inferiority, which cannot possibly be defended. That the duties of these officers are of a combatant nature has at least been recognized by the Admiralty, by their decision that the engineers under the new scheme, and who are now mere boys, are to be military officers, and rightly so, as they are an indispensable part of a fighting organization, and, as such, should have a recognized military status and internal control of their departments. The officer who administers his depart-

ment wisely under present conditions, when he has nothing to rely on save his own personal influence over his men, may be trusted not to abuse authority when he is given power to exercise it. The midshipmen of the new entry are already serving in the engine rooms of several ships under orders of engineer officers, so that a difficult position has already been created, the gravity of which will increase the longer it remains untouched. The menace to discipline is a positive danger, which can only be removed by adequate recognition of the engineering branch as an essential part of the military branch of the Service, with the restriction, however, that engineer officers should never command ships, but should be eligible for any administrative position that can be held by those officers of the new scheme who devote themselves to purely engineering duties.

THE DEVELOPMENT OF THE SELBORNE SCHEME.

"But the time has come when the position as affecting the future must be studied in some detail. The institutions have hitherto refrained from criticising the Selborne scheme and its subsequent modifications, in the hope that the Admiralty would develop it with due regard to the engineering efficiency of the Service. It has now reached a phase, however, when some forecast of its development can be arrived at, and I can only say that its tendencies cause grave misgivings, and, in my opinion, its scheme must either be amended to conform to the originally expressed intentions of 1902, or it will end in failure. I have no wish to condemn it entirely. There is much that is good in it, but as it is being molded, it is evident that the efficiency of the engine-room staff will be reduced. Let me explain more fully.

"As originally proposed by Lord Selborne, the intention was that the officer who took up engineer duties would specialize permanently and identify himself with engineering throughout his career. Subsequently a committee, presided over by Admiral Douglas, decided that the officer need spend only a few years in the practice of engineering, and leave it on promotion to commander for the line of command pure and simple. Pos-

sibly this modification was found desirable in order to render the engineering branch more attractive to the cadets, as, while they see the disabilities under which the engineer officers now labor, and the evident degradation of the branch, they are not likely to be fired with enthusiasm to enter it, lest they in the end find themselves sharing the same fate. Marine engineering is surely big enough for any man's life work. It is, therefore, with the gravest concern that we contemplate the replacement of the present officer, who devotes his whole mind and life to his work, by a *semi-amateur*. What will be the position of the latter? His lack of practical training and experience will render him dependent upon his artificers, who, combining the position of engineer and artisan, will become the *working engineers* of the new scheme, under a *departmental head*, who will be more or less *ornamental*, and certainly not enthusiastic. But the mischief does not end there, for the artificer in his turn is to be supplanted by a man who is, to quote the official description, 'not a mechanic and not intended to be such." To thoughtful engineers these statements will seem almost incredible, but they are true. How, then, is this pit of destruction, which the Admiralty have dug, to be avoided?

"In the first place, by prompt recognition of the military status of the engineer branch, so that the fusion which Lord Selborne foreshadowed may become a reality.

"Secondly, the training should be adequate for the increasing influence which machinery has on the fighting efficiency of our warships.

"Thirdly, the specializing must become permanent, ensuring the attainment of that accumulated experience which engineering success demands, and upon which it depends.

"Then, and then only, shall we feel that the policy which controls the engineering branch of the Service is prompted by adequate appreciation of what is expected from our naval engineers in time of war."—"Page's Weekly."

COMPREHENSIVE RESEARCH IN MARINE ENGINEERING.

In the practical work of designing ships and machinery to fulfil novel and more drastic conditions than were imposed for previous trials of similar types of vessel, builders are repeatedly faced with the ironical discovery that if only they had taken certain observations during the trials of those earlier similar vessels they would be in a very much stronger position in tendering for the new work. Again and again this occurs, and in referring to past records, or to certain special trial results, one is very frequently struck by the lack of some important data. With how many ships each year, for instance, are progressive trials made? Of those few ships most are built by firms who have not access to a model tank, and can consequently only arrive at the effective horsepower within wide limits, so that no definite determination of propulsive efficiency is possible. In an amazing number of cases accurate speed trials are not carried out at all with merchant vessels, and even when they are made important data that could easily be acquired are not taken. It would be interesting to know whether the boiler efficiency or the thermal efficiency of the main engines has been accurately ascertained in a dozen cases—warships excepted—in the last dozen years.

To illustrate more clearly what we mean, take the case of a fast Channel steamer or a big intermediate liner. How often has the water consumption been measured accurately? Feed-pump strokes may be counted and indicator diagrams taken, but no effort whatever is made to determine the quality of the steam as it enters the engine. Yet we know from very precise tests of land engines that the effect of moisture, which is generally due to incorrect boiler proportions, is very marked on economy, especially with turbines. The measurements generally made on marine trials is that of coal consumption and horsepower for the top speed. The fact that the ship's machinery requires two pounds of coal per indicated horsepower per hour tells us nothing of value beyond indicating a mediocre degree of economy of the entire machinery and leaving the commercial value of speed for a given coal consumption at

a lower and possibly more efficient condition of power quite undetermined. To be of any use the trials of a ship should be carried out in such a way that we can arrive at a series of efficiencies and not merely obtain the total consumption of a fuel of, generally, unknown calorific value. No merchant running a large general business is content at the end of a year to know his revenue and his expenditure only; it must be set forth in very elaborate detail for each department, and the value of the accumulated data for indicating relative profit or loss and the general tendency of business is absolutely essential. Why it is that marine trials are not similarly conducted we cannot say, but that they might be with advantage there is no doubt. Shipbuilders, however, rarely carry out trials on a thoroughly comprehensive basis. Exact data on the efficiency of ship propulsion as evidenced by the carefully recorded component efficiencies forming the total are almost non-existent, with the result that on many points we are lamentably short of information. Omission to collect all possible information is a fault for which there is no excuse. The cost of obtaining it is very small in proportion to the interests at stake, but, nevertheless, the principle of systematic and comprehensive research by shipbuilding firms is generally ignored. Not because its value is not appreciated, but because it might delay the final completion of the ship, or perhaps because it might cost time and take trouble; possibly it would occasion some inconvenience in accommodating extra hands in the record party; but whatever the cause, the opportunity is wasted. One of the instances we can most easily call to mind was the omission on the part of the Admiralty staff to take torsion horsepower records on the trials of the *Amethyst* and *Topaze*. In this case the value of the data would have been very great, on account of the elaborate nature of the other trials, but for comparison with modern turbine vessels, except on a basis of ship proportions and speed, the *Amethyst's* results are almost worthless scientifically. True, the data acquired compared with that of the *Topaze* gave all that was wanted at the time, but for future reference it was hopelessly inadequate. Again, in the case of the *Dreadnought*,

no attempt was made to measure the pressure drop along the turbine barrels. For the new vessels the turbine blading has been altered with the idea of gaining a better distribution of power, but a detailed analytical comparison is impossible because of the lack of data from the *Dreadnought*. In her case the water consumption with and without cruising turbines was not measured; yet, at the present time, when the question is being strongly debated as to whether it is or is not worth while to fit cruising turbines, the convincing information that would have been gained is lacking. A point occupying wide attention nowadays is the effect of depth of water on speed, yet ten years ago trial-trip records were innocent of any note of this, and results obtained then must frequently be discarded as doubtful simply owing to the lack of information on this point. To ignore depth entirely simply involved useless results, and anyone who analyzes the results of some of the older cruisers, or even those of the *Good Hope* and County class, must experience a sense of annoyance that more care was not taken to secure accurate and valuable data.

This disregard of comprehensive research is bound to be disadvantageous in the near future in all directions. Condenser practice, for instance, is badly in need of reform, but exhaust temperatures, or the temperatures of air-pump suctions, water inlet and outlets, or at various points in the condenser, are seldom taken. Even if they are, no attempt within our knowledge, excepting in one or two cases within the last two years, has ever been made correctly to determine the quantity of cooling water passing through a condenser, though it can, of course, be calculated approximately. The result is that nearly all marine condensers are designed on empirical data of the most unscientific description, and reference to the past practice of a company, as revealed in its trial-trip records, is of no assistance whatever in future designs. This work of investigation is yet to be done before we can make as much progress as has recently been made in condensing plants for land work. The necessity of proportioning all machinery on a basis of steam consumption, which has been enforced by the

adoption of the steam turbine, has been of immense benefit in forcing marine engineers to a greater appreciation of separate efficiencies of the component parts of their installations, as opposed to a more general estimate of the performance of the whole. If we turn to one or two leading text-books in marine-engine design we find them replete with references to ratios based on indicated horsepower. It is still too early, we suppose, for an adequate exposition of turbine design—the publication of such information generally causes great objections to be made by interested parties—but some time it will be more adequately recognized that a turbine cannot be designed without fixing steam consumption, and that "horsepower per square foot" of anything avails us nothing in comparing the two types of machinery.

Now, if adequate data had only been taken on previous trials, it would be easy to make a very reliable basis of comparison between types of boilers or types of engines, but this is not possible on account of this omission. Why is it that some firms making condenser equipments for power stations are able to obtain remarkable economical results from about 0.7 square foot per horsepower when marine engineers have to go to the square foot or more? Simply because they have studied temperatures and taken the trouble to acquire data on the subject. The whole question is one of profit and loss—is the expenditure of a few pounds on extra investigations on trial trips worth making if a saving can be made in the size and cost of machinery in a future job? Only one answer is admissible, even if a dozen ships are thoroughly tested and only one is successfully modified as the result of previous research.—"The Engineer."

PRACTICAL THERMODYNAMICS.

The last fifteen years have marked a noteworthy change in the meaning commonly attached to the thermodynamic efficiency of a steam engine. Up till a very few years ago such efficiencies were estimated by comparing the total work done

with the total expenditure of heat, a procedure which led to the somewhat disheartening result that, reckoned on this basis, the efficiency of the very best steam engines did not exceed some 18 per cent. or so. In practice the coal consumption, reckoned in pounds per horsepower per hour, was, and to a large extent still remains, the customer's criterion of efficiency, but suffers from the drawback of not apportioning the total losses between the boiler, the engine and, in these days of turbine and high vacua, we should, perhaps, add the condenser. Electric-power station engineers were the first, as a body, to appreciate the importance of separating the boiler and engine losses. Thirty years ago few engine builders were prepared to guarantee steam consumptions, though they had a fair general idea as to the fuel needed per horsepower hour. As standards of efficiency rose, however, builders recognized the necessity of protecting themselves from losses due to bad stoking, bad boilers or other causes not under their direct control; whilst station engineers, to ensure low generating costs, found it essential to separate questions of boiler efficiency from those inherent in the design and construction of the engine, and hence guarantees as to steam economy are now as common as they were rare thirty years ago.

The late Mr. Willans was, we believe, the first manufacturer to appreciate the advantages of referring questions of engine efficiency to the efficiency of an ideally perfect steam engine working under corresponding conditions, in place of to the absolute standard already referred to, which ignores the inherent imperfections of all heat engines. Referred to this standard, however, non-condensing engines showed themselves markedly superior to the condensing type, in spite of the lower steam and fuel consumption recorded with the latter. This paradox occasioned some difficulty to those who failed to realize the very ineffective use which the reciprocating engine is able to make of its condenser. This practically insuperable defect became startlingly obvious with the introduction of the condensing steam turbine. Worked non-condensing the steam turbine is notably inferior in its performance to the best recipro-

cating engines, but the addition of a condenser placed it at a single bound at the head of the list. Nevertheless, some station engineers still fail to appreciate the all-importance of preventing air leakage into condensers for turbine machinery. On not a few occasions complaints to builders that the steam turbine was failing to maintain its initial economy in the matter of fuel have turned out to have arisen solely through a neglect to stop air leakage into the condenser. Station engineers have not uncommonly been drawn from the merchant marine, a choice which experience has thoroughly justified. With the ordinary marine engine, however, the difference in the fuel consumption corresponding to the use of a 26-inch in place of a 28-inch vacuum is almost immaterial, being about 1 per cent. or so, whilst with a turbine a reduction of 2 inches on a 28-inch vacuum sends up the consumption by 11 to 12 per cent. Even now this difference between the two types of prime mover is not always realized.

The introduction of the steam turbine has, nevertheless, done much to popularize the idea that in heat engines only a portion of the heat energy added to the water in the boiler is "available" for the production of mechanical work, but difficulties are still experienced in endeavoring to attach a satisfying physical meaning to entropy. In his recent presidential address to the Institution of Junior Engineers, Mr. James Swinburne points out that in certain cases, at any rate, an increase of entropy corresponds to an increase either in the "range" or the "intensity" of the molecular motion of a gas. If a gas is expanded isothermally, the average velocity of its molecules is unaltered, but their "range" of movement is increased, the mean free path being greater than before the expansion. Since heat has been added the entropy has also been increased, so that in this case the change of entropy has been coincident with an increase in the range of the molecular motion. If, on the other hand, a gas is heated at constant volume, this range of movement is unaltered, but the velocity of the motion is increased, so that here the augmentation of entropy corresponds to an increase in the intensity of the molecular motion. In adiabatic expan-

sion, on the other hand, the increase in "range" is exactly compensated for by the decrease in "intensity."

Perhaps the easiest method of picturing a growth of entropy is furnished by Joule's famous experiment, in which air compressed into one vessel is suddenly allowed to expand through a stop-cock into another originally vacuous. After equilibrium is established the temperature of the gas is found to be unaltered; but the entropy has been greatly increased. It is sometimes claimed that in such a case no heat has been added during the expansion, and that therefore there should have been no increase in the entropy. As a matter of fact, this idea is incorrect. The initial stage of the process—viz: the rush of the gas through the stop-cock—may take place nearly adiabatically, and the jet, accordingly, issues with a considerable velocity. Since such a velocity has a definite direction, the jet of gas is possessed of high-grade energy, which, under suitable conditions, could be employed in accomplishing mechanical work. At the end of the operation, however, when the steady state has been obtained, this "directed" velocity of the jet, as a whole, has been wholly converted into a random motion of the individual molecules, or, in other words, has been returned to the gas in the form of heat.

In all the instances given above it is possible to associate certain physical changes, easily visualized, with the growth of entropy; but these physical changes appear to be rather concomitants with the increase of entropy than this increase itself. It is easy, indeed, to find cases in which the growth of entropy has no connection with a change either in the range or the intensity of the random motion of the molecules of a system when that system is considered as a whole. Thus if heat flows by conduction from one portion of a gas to another, neither the range nor intensity of the random motion of the molecules, taken as a whole, is altered, since the random kinetic energy lost by the hot portion is gained by the cooler portion. The entropy has, however, increased, but the only net physical change has been an increase in the uniformity of the total mass.

There is some reason for believing that every lack of uni-

formity in Nature constitutes a source of high-grade energy. If the chemical atoms are unstable, as some assert, the energy liberated in their break-up is undoubtedly high grade, but is ultimately degraded into heat. If this hypothesis of atomic disintegration be correct, the ultimate end of the universe will be reached when the whole of the atoms now in existence have completely broken up, and all parts of space are uniformly filled with the fragments, all of which are identical *inter se*. The entropy will then be a maximum.

Since so many different physical processes are associated with changes in entropy, it seems useless to try and identify entropy with any particular one, and the concept should be taken as merely a mathematical convenience associated with, but not constituted by, many different physical changes. Its usefulness to those engaged in practical application of thermodynamics is now generally recognized, and its numerical values are regularly tabulated in all the best steam tables.

In this latter connection it is interesting to note that all the tables now in common use are based upon the work of Regnault, executed some sixty years ago. The accuracy of this experimenter's determinations is now challenged, since the most reliable of modern experiments show considerable errors in Regnault's estimate of the total heat of steam. Thus in the "Physical Review" of last February Professor A. Whitmore Smith gave a table of the latent heats of steam between 0 degree and 100 degrees centigrade, based upon a comparison of the most reliable modern experiments; and in the November issue of the "Journal of the American Society of Mechanical Engineers," Dr. H. N. Davis extends the comparison to higher pressures, and concludes that the true total heat of steam is given in B. T. U. by the value—

$H = 1{,}150.3 + 0.3{,}745\ (t - 212) - 0.00{,}055\ (t - 212)^2$, in place of Regnault's value

$$H = 1{,}091.7 + 0.305\ (t - 32).$$

At boiling point Regnault's value is 1,146.6 B.T.U., whilst the new formula gives 1,150.3. At freezing point Regnault's

value was 1,091.7 B.T.U., as against 1,073.4 by the Davis formula. At 200 pounds pressure the two formulæ are practically identical, but at higher pressures Regnault's value is too large, the error being 5.2 units at 300 pounds pressure. The error is, it will be seen, a maximum at condenser temperatures. Comparing the new values with the old, it appears that efficiency ratios estimated by the latter are, however, very little affected even in the case of exhaust-steam turbines. If such a turbine, taking steam at atmospheric pressure, and expanding it down to a 28-inch vacuum, had an efficiency ratio of 68 per cent., as calculated by the old figures, its true efficiency ratio would appear to be about 67.6 per cent., or about ½ per cent. less. With high initial pressures the errors appear to be even smaller, so that there is no immediate necessity for scrapping existing tables.

Dr. Davis makes an interesting application of his equation for the total heat of steam, to fix the relative reliabilities of the values for the specific heat of superheated steam found by Messrs. Knoblauch and Jakob and by Professor Carl Thomas, respectively. It is easy to show that, having accurate total heats, and an accurate knowledge of the specific volume of slightly superheated steam, the specific heat of the latter at the saturation temperature can be calculated by the general principles of thermodynamics. Making such a calculation, Dr. Davis finds that his results are in very much better agreement with the Munich experiments than with those made by Professor Thomas, which fail even to indicate the general trend of the curve in the neighborhood of the saturation line. The error is attributed to the presence of particles of moisture suspended in the steam during the tests made by Professor Thomas. Messrs. Knoblauch and Jakob found that such particles could exist in the midst of slightly superheated steam for an appreciable time before being evaporated, and the requisite time for this to take place was not allowed in the experiments at Cornell. A description of the Munich experiments, the general reliability of which seems now well established, will be found in our issues of March 15 and April 12, 1907.—"Engineering."

THE BOARD OF TRADE REPORT ON BOILER EXPLOSIONS.

The annual reports to the Secretary of the Board of Trade on the working of the Boiler Explosions Act must be read between the lines in order that the full value may be got out of them. Unfortunately, they leave the impression that the reporters—that is to say, the Commissioners—appointed to ascertain the how and the why of boiler explosions undertake every inquiry with the full conviction that someone is more or less criminally responsible; that, in fact, such a thing as an unforeseen boiler explosion is unthinkable. They assume in all cases, under all circumstances, that the boiler announces that it is going to blow up; and the announcement is so strenuous and so blatant that nothing but gross incompetence or criminal negligence can explain the circumstance that the announcement has been neglected. When circumstances arise which prove that this view is not invariably accurate, then we have at best a grudging admission that, after all, no one was to blame. We think the pronouncements of the Commissioners would be more convincing if they were more human; if, in a word, there was a more frank expression of belief that, after all, some catastrophes are inexplicable; and that in others lack of vigilance had nothing to do with particular events.

On the whole, the figures before us are unsatisfactory. Sixty preliminary inquiries and seventeen formal investigations have been held respecting boiler explosions, or so-called explosions, during the twelve months ending June 30th, 1907. It will be seen that the Board of Trade is not given to hustling these reports through the printer's hands. During the period named there were 77 "explosions," causing the deaths of 28 persons and the injury of 65. If we compare this with the preceding year, we see that there was an increase of 23 in the number of explosions, the number killed and injured in 1905-6 being 25 and 21, respectively. If we examine the record of 25 years we have no reason for self-congratulation. The operation of the Act has apparently brought about no steady improvement; on the contrary, the figures remain irregular to a degree; no even curve could be plotted from them. Thus in the

first year after the passing of the Act there were 45 explosions and 35 lives lost. In 1887-8 there were 61 explosions and 31 killed. In 1894-5 the explosions were 114 and the deaths 43. The best year of all was 1905-6, with 54 explosions and 25 deaths. It does not appear that the failures have any traceable connection with the number of boilers, with the trade of the country, or, indeed, any definite factor. That a large percentage of explosions is due to negligence and ignorance is certain, and these cases ought to be attacked in the way which we have over and over again advocated in our pages, and to which we have never yet heard the smallest objection advanced. It is, simply, that every owner of a boiler which explodes should be put on his trial for manslaughter if anyone is killed. If he is not to blame he will have no difficulty in clearing himself. If a man bought a rusty old cannon and fired it off close to the roadside on Guy Fawkes' day, and the gun burst and killed a bystander, he would certainly be tried for manslaughter. In what respect would his action differ from that of the man who buys a rusty old boiler for a few pounds, and uses it in the middle of a crowded farmyard? Why should he get off with a fine of a few pounds when two or three men are killed? There are plenty of examples of this kind given in the report. On the other hand, we have cases where it is very difficult indeed to apportion blame, or say that any one was negligent or ignorant. A boiler explosion is the result of a crack, or grooving, or corrosion, in some inaccessible place. The inspector has no reason to suspect the existence of any defect of the kind. To get at the place might mean stripping the boiler, or interrupting the work of a factory at a very busy time. The boiler gives way, and then the Commissioners, wise after the event, say that the existence of the weakness ought to have been discovered. In France and Germany and Austria, where Government interference is active, it does not appear that boiler explosions are smaller in number or less fatal than they are in this country. If all boilers were insured, and the advice of the insurance companies' officers was taken promptly, there would be a considerable diminution in the number of explo-

sions; but it would be a blunder to suppose that absolute immunity would be secured. The insurance companies can only deal with structural defects; those of management are, of course, beyond their control. But there are hundreds of dreadfully bad boilers bought and sold and used every year, in spite of the fact that no insurance company will look at them; and the market for these things will never be stopped until, as we suggest, the owners find that they run the risk of being tried for manslaughter if they use them.

Of the seventy-seven "explosions" recorded, no fewer than eleven were fractures of pipes, valve chests, etc., brought about by water hammer. Details are lacking, but so many catastrophes followed the opening of drain cocks, that we are disposed to agree with one of our correspondents this week, and say that drain cocks should not be fitted to steam pipes at all. The only way to secure safety seems to lie in having only one stop valve close to the boiler which may be controlled from the engine house by an electric current. A steam trap could be fitted near the engine; yet we are not sure that the immunity secured in this way would be worth the trouble and expense. No attempt whatever is made by the Commissioners to explain why opening a drain valve should set up water hammer. This is, we may add, one of the most interesting questions ever asked by the steam user. In one case the report states that a ½-inch drain was too small. What is the right size for a drain cock? What proportion should it bear to that of the pipe on which it is fitted?

It is gratifying to find that in one case only—that of the thermal storage cylinder at Greenwich, fully reported in our pages during the progress of the inquiry—did any question arise as to the quality of the materials employed; and in that case the Commissioners decided that the material was perfectly satisfactory. Leaving the water-hammer cases on one side, nearly all the catastrophes seem to have been due to weakness, mostly the result of old age or disease, and presented nothing abnormal, or claiming special consideration at our hands.—"The Engineer."

WATER HAMMER.

Many of our readers will remember that on November 13th we published a letter from Mr. Stromeyer on water hammer. That letter was a comment on an article which appeared in our pages the preceding week, in which we referred at considerable length to Mr. Longridge's annual report to the Engine, Boiler and Employers' Liability Insurance Society, Manchester. Mr. Stromeyer had been found unintelligible by some of our readers, and in reply to requests for elucidation, he promised that one should be forthcoming at an early date. We find it in the pages of his annual report to the Manchester Steam Users' Association for 1907, a paper read before the Manchester Literary and Philosophical Society in 1901, and a second paper on "Steam Pipes," read before the Manchester Association of Engineers in 1902, which he has sent us. The last paper may be taken as the clearest practical exposition of Mr. Stromeyer's views on water hammer. He begins by expressing the conviction that technical societies abhor mathematics, and then goes on to set forth, at all events without the aid of the differential calculus, what his explanation of the phenomena is. It may be remarked in passing, that it is interesting to note how briefly, and yet lucidly, he has succeeded in saying without mathematics, outside very simple arithmetic, all that is involved in pages of mathematical disquisition in the paper read by him the previous year.

Mr. Stromeyer divides his subject. He in a manner classifies it under two heads. First, the reason why water hammer bursts cast-iron pipes and stop-valve casings; secondly, the cause of water hammer. More than two thousand years ago the old Greek philosopher asked the world what would happen if an irresistible force encountered an insurmountable obstacle? Mr. Stromeyer essays to find the answer. The irresistible force is moving water; the obstacle, unfortunately not quite insurmountable, is the pipe or the stop valve. Possibly without being aware of it, he follows in a measure the lead of Dr. Le Bon. That physicist shows that in matter there is an enormous store of energy, due to the almost inconceivable velocity with

which radiant matter can be sent off into space. On the other hand, an enormous "force" can be set up by the sudden arrest of a body in comparatively slow motion. There is a story told of a man who was seen in hospital by a friend, who asked him, "Was it the fall off the scaffold that hurt you?" "No, Tom," was the reply, "it wasn't the fall, it was the stopping so quick." Mischief is done by water hammer because the water is stopped so quickly; and inasmuch as cast iron, not having much "give" in it, stops the flying water more quickly than wrought steel does, accidents occur with the former of a kind unheard of with the latter. To understand and appreciate Mr. Stromeyer's views it is essential to give a little example. Let us suppose that we have a mass of 1 pound moving with a velocity of 32 feet per second; fractions are not necessary. The energy expended on it has been 16 foot-pounds; that is the energy which it can give back. But the energy may be given out in various ways. It will suffice to lift 1 pound sixteen feet, or 16 pounds one foot, or 192 pounds one inch, or 1,920 pounds one-tenth of an inch, or 19,200 pounds one-hundredth of an inch, and so on. By reducing the distance over which the energy is to be expended we can augment the "force," until at last we may get from a few grains an enormous effort. Mr. Stromeyer treats water as an exceedingly incompressible elastic body, and he sets himself to calculate—in one paper at great length and with much mathematics—the precise "force of a blow." His calculations lead him quite naturally to surprising figures. Thus, if a bar of steel of 1 inch sectional area was dropped on a rigid anvil with a striking velocity of 10 feet per second it would produce a pressure of 7.9 tons. He does not give the weight of the bar. The pressure would last for one-eighty-five hundredth of a second. From this he deduces that if a plug of water be projected through a distance of only 1 inch a pressure of 800 pounds per square inch may be set up; and that, in fact, the presence of a mere "bubble of vacuum" may cause a catastrophe. The whole essence of his argument depends on postulating rigidity in the anvil. If any motion can take place in it—if, that is to say, it can yield at all—then the

"force of the blow" will be reduced. Mr. Stromeyer admits that cast iron is not quite rigid, and that prevents catastrophes; while mild steel, being much less rigid, no accidents occur from water hammer when steam pipes are made of it. It is enough, perhaps, to point out here that both Mr. Stromeyer and Drs. Hopkins and Ritter, whom he quotes, deal with conditions which have no existence in nature. All their calculations require modification, in the sense that, as we have said, the "force of a blow" is a thing which cannot be expressed in any general terms. Thus the force of the blow of a hammer on the head of a nail depends on the resistance offered by the wood into which the nail is being driven. Mr. Stromeyer admits this, and writes: "Considerable reductions in these estimated pressures have undoubtedly to be made on account of the elasticity of the material of steam pipes, but even then the pressures will be very intense."

Admitting that water can give a blow which will burst steam stop-valve casings, the question remains—How is the mass of water put in motion? On this point Mr. Stromeyer has nothing new to say. Water lying in the bottom of a steam pipe is caught up and projected. In order to account for the existence of a rush of steam the aid of a vacuum has to be invoked. The argument runs thus: There is a rush of steam in a pipe toward the closed end of it. No rush could take place unless there was a vacuum. Therefore there must be a vacuum. We confess that we hold that this theory is not one fit for general application. Water hammer takes place under conditions which render the action of a vacuum to the last degree improbable. We quote the following typical case from Mr. Stromeyer's 1907 report: "A few years ago a very long steam pipe, lying at a slant of about 1 in 20, was being slowly drained by means of a cock at its lower end, steam being introduced at its top end. The pipe was several hundred feet long, and suddenly burst near its middle, presumably near a point to which the water-level had been lowered. The action was probably as follows: The pipe, a 6-inch one, being slightly inclined, there would be a water surface of about 10 feet long, or longer if

locally the pipe was nearly level; the top surface would be hot water, but as the water level was being lowered, cold water would in a way adhere to the walls of the pipe and come to the surface. Here it would cause condensation of the steam and create the turmoil explained above, which would result in water-hammer blows."

Now, here it is evident that as the water was being slowly drawn off, it is to the last degree improbable that any large chilling surface was suddenly exposed to the steam. On the contrary, condensation would have gone on quietly, the pipe being gradually warmed up. But this is not all. If a body of water had been picked up it would have been flung forward against, say, a stop valve. But no action of this kind took place. The water lay at the lower end of a "very long pipe," which burst apparently more than a hundred feet away from the water. The steam came in, be it remembered, at the end farthest from the water. If this smash was due to water hammer, then nothing more inexplicable has been recorded. Again, Mr. Stromeyer mentions a case in which the exhausts of a number of engines could either be delivered into the air or into a great main 3 feet in diameter leading to a condenser. In this main was a bend. Repeated water hammer occurred at this bend, and ruptures resulted. The hammering took place whenever the exhaust of any of the engines was changed from being delivered into a long overhead pipe to being delivered into the condenser main. Mr. Stromeyer admits that while it is possible to assume that waves were produced from water brought in with the exhaust, there is nothing to explain why these waves should have been so large as to fill a 3-foot main, nor why a wave should have been arrested near the bend instead of being driven into the condenser. Again, it is well known that pipes rupture circumferentially. Cases of this kind are not covered by Mr. Stromeyer's theory. He skims over this fragile ground with the remark: "It is not evident why this form of rupture should occur unless the water-hammer blow was too weak to cause the ordinary longitudinal rupture, but assisted any local bending strain to do what neither

power could do alone." Just what this means we have failed to satisfy ourselves.

It appears to us that, after all, Mr. Stromeyer has, unfortunately, left the whole matter just where it was. Apparently some cases of water hammer are brought about as explained by his ingenious hypotheses; others are not. One of the difficulties is that if the facts were precisely as he supposes, smashes would be of daily occurrence. As it is, they are exceedingly rare—by comparison. That is to say, there are thousands of steam pipes and stop valves, and the latter are opened and closed hundreds of thousands of times in the course of a year without causing any accident or catastrophe whatever. If Mr. Stromeyer could but see it, the sweeping nature of his theory, and its entire completeness, renders its soundness problematical. There is such a thing as proving too much.—"The Engineer."

CYLINDER CONDENSATION.

The letters which will be found on another page addressed by M. Bollinckx, of Brussels, to the late Bryan Donkin possess considerable interest. It is true that they were written fourteen years ago, but they are just as applicable to existing conditions now as they were then. The pursuit of economy in steam engines has for many years centered on one object. Let cylinder condensation be stopped and all the rest will follow. At one time it was believed that this was a simple thing and easy to do. The falsity of that faith has long since been demonstrated. Cylinder condensation will never be stopped unless we know precisely to what it is due. The knowledge may only serve to prove that it never can be stopped; but even that would be a gain. The advocates of superheating maintain that they have solved the problem; but it remains to be proved that the solution is applicable in general practice—that the remedy is not more costly than the disease. So far, at all events, it seems to be clear that the moderate and highly useful degree of super-

heat that is commercially successful does not entirely stop cylinder condensation, but only reduces its amount.

It will be seen that fourteen years ago M. Bollinckx pinned his faith on jacketing. To the minimization of clearance space he attached little importance. He took the steam for the high-pressure cylinder into the jacket at the top, so that all priming water and condensed steam might run down to the bottom and then be drained off. The cylinder walls he made very thin, and supported them by rings, which acted the part, he hoped, of "gills," so as to render the action of the jacket steam more powerful. In effect, he cast his cylinders thick, and then turned deep grooves in them. He ribbed his cylinder covers and his piston faces. He polished all the surfaces over which steam passed, and he tried to jacket his pistons. It does not appear, however, that the results obtained fulfilled his hopes. He refers to a curious experiment which will be new to many of our readers, made by Donkin with a Sulzer engine. High-pressure steam was admitted to the cylinder during the compression period by an auxiliary valve. M. Bollinckx is much surprised to find that this was not accompanied by a rise in the compression pressure—a fact which goes to prove, he says, the enormous condensation which must take place during admission. Unless the cylinder surfaces have "a certain temperature," it is obviously impossible that the pressure can rise during compression. Here we may remark that the phenomena of compression in a steam-engine cylinder are quite complex and little understood. Adiabatic and isothermal compression of permanent gases may be dealt with easily enough. But matters are quite different when we are working with the most unstable fluid that exists. All that can be predicated with reasonable certainty is that the compression pressure will be less than by calculation it ought to be; and that if the weight of water present is greater than one-third of that of the steam, after a certain point has been reached the compression pressure will no longer rise—the steam will be liquefied. To all intents and purposes the result is the same as though the water absorbed the steam just as it would CO_2.

It has been a favorite contention with those who treat the steam engine on theoretical grounds that a material advantage would be gained by filling the jacket with steam much hotter and of a higher pressure than that passing into the engine. This has been tried many times, but given up. The gain was not worth the risk incurred by carrying a heavy pressure in the jacket. M. Bollinckx is troubled in mind because he finds that the advantage derived in this way is minute, whereas it ought to be considerable. Also he has constructed a compound engine in which the low-pressure cylinder and the intermediate receiver were jacketed with steam having a pressure of 90 pounds, and yet the economy was not better than that obtained when the intermediate receiver was not jacketed at all, and the low-pressure jacket simply contained the steam passing through it from the high-pressure cylinder to the low-pressure cylinder. He can give no explanation, unless it is that there is not enough circulation in the jacket. Further than this, "Je n'en sais rien, mais le fait brutal est là." After referring to the effect of wire-drawing, he refers to statements made by Hirn and Hallouer, which we confess are quite new to us, to the effect that wire-drawing by the use of small ports may be such efficient a means of economy that expansion gear is unnecessary; and the speed can be regulated without loss of economy with an ordinary butterfly-throttle valve.

Many years ago we suggested in our pages the filling of jackets with heated water, its temperature to be raised by a system of pipes in the flues or uptake, so as to utilize the waste heat. This water might be caused to circulate as in the high-pressure hot-water system used for warming buildings, or by a force pump. If objection were taken to water because of the pressure, then we pointed out that oil might be used. It will be seen that M. Bollinckx holds that the oil system would not work because the oil could not part freely with its heat to the metal. We have here the old phase of the whole problem. It is not enough to provide heat; we have to transfer it from one body to another. In this connection attention may be directed

to a point of special interest of which sight is usually lost. We are told continually that the reason why the jacket will not work is that it has to transmit its heat through the thickness of the metal; but in the case of Watt's earlier engines, the piston worked in an atmosphere of steam, instead of one of air, and it does not seem possible that any so-called initial condensation could take place. Condensation, if any occurred, must have been continuous during the time the engine was coming indoors; but putting this on one side as not strictly parallel, we may say that a double-piston engine has been tried in Belgium. The two pistons are on one rod in a cylinder more than two strokes long. Boiler-pressure steam always lived between the two pistons when the engine was at work, and, of course, heated up the cylinder directly in advance of the piston for each stroke. We cannot find, however, that this engine was abnormally economical. It was patented about 1903 by M. Francois, an engineer in the Cockerill Works, Seraing. In another form the same idea was embodied in an engine patented in this country a dozen years previously. An engine was tried, and with steam slightly superheated—63 degrees to 83 degrees Fahrenheit—it developed about 110 I.H.P., with 16.8 pounds to 17.5 pounds of steam per horse per hour, depending on the superheat. This was a very fair result for a non-condensing engine; but it is obvious that the superheating played an important part.

As we have said, things are in the same position now that they were fourteen years, or, for that matter, twice fourteen years ago. The dispassionate onlooker sees two parties—one convinced that the jacket is essential to economy, the other that it does more harm than good. Each is prepared to prove his contention, and does prove it. But, curiously enough, the same engines can be used by both parties to support their own views. This is the reason, no doubt, why the Institution of Mechanical Engineers' Committee on Steam Jackets has up to the present been unable to arrive at any fixed conclusions whatever.—"The Engineer."

STEAM TURBINES IN THE NAVY.

Considerable interest attaches to the trials of British warships during the year, as the majority of the vessels are fitted with Parsons turbines; but before dealing with these it may be stated that the few vessels already in commission fitted with this system continue to give most satisfactory results. The *Dreadnought* has finished two years' commission, during which she has done an exceptionally large amount of steaming. In fact, under the new régime the ships are at sea for a much longer period of time than has ever before been the case. This is all for the good of the service. Notwithstanding this greater amount of steaming done, and the frequency of stopping and getting under way at a changed rate of steaming, the cases of temporary disablement have been remarkably few, and show that the engineering branch of the Navy is in a high state of efficiency.

In Table I the results are given of official steam trials of the new ships of the armored class finished for the Navy during the past year. The battleship *Lord Nelson* and the cruiser *Defence* are fitted with reciprocating machinery, and both installations have been fully illustrated in "Engineering." The *Lord Nelson's* propelling machinery was fully described on pages 293, 398 and 421 of vol. lxxxvi., and that of the *Defence* on page 835 of the same volume. The *Bellerophon* and the three cruisers of the *Invincible* class are, however, fitted with turbine machinery. Most interest attaches to the coal consumption. It will be noted that at full power the average rate for the four ships was rather under 1.5 pounds of coal per horsepower hour. The *Indomitable* returned the remarkably low rate of 1.2 pounds, which, of course, includes the fuel necessary for running all the auxiliary plant. The two reciprocating-engine ships averaged 1.9 pounds. Objection may be taken to such a comparison because of possible variants. The mean result for the three cruisers of the *Invincible* class is under 1.5 pounds, whereas in the case of the three cruisers of the immediately preceding class—the *Minotaur* trio—the average con-

Table I.—Steam Trials of His Majesty's Armored and Protected Ships in 1908.

Name of ship.	Type of ship.	Builders of ship.	Makers of machinery.	Displacement.	Type of boiler.	First 30 hours' trial.		Second 30 hours' trial.		8 hours' full power.	
						I.H.P.	Coal per I.H.P. per hour.	I.H.P.	Coal per I.H.P. per hour.	I.H.P.	Coal per I.H.P. per hour.
Lord Nelson	Battle-ship.	Messrs. Palmer.	Messrs. Palmer; reciprocating engines.	16,500	Babcock & Wilcox.	3,630	2.2	12,200	1.9	17,400	2.0
Bellerophon.	do.	Portsmouth Yd.	The Fairfield Engineering Company; turbines.	18,600	do.	4,910	2 5	16,700	1.7	24,000	1.5
Defence.....	1st class cruiser.	Pembroke Yard.	Messrs. Scott; reciprocating engines.	14,600	Yarrow.	5,780	1.9	19,500	1.8	27,500	1.8
Indomitable.	do.	Fairfield Engineering Co.	The Fairfield Engineering Company; turbines.	17,250	Babcock & Wilcox.	8,480	2.6	29,300	1.6	43,700	1.2
Inflexible....	do.	Messrs. J. Brown & Co., Ltd.	Messrs. J. Brown & Company, Ltd.; turbines.	17,250	Yarrow.	9,130	2.3	31,400	1.8	43,300	1.7
Invincible....	do.	Messrs. Armstrong, Whitworth & Co.	Messrs. Humphrys, Tennant, Ltd.; turbines.	17,250	do.	9,300	2.3	31,500	1.6	44,800	1.5

sumption at full power was 1.8 pounds, and in the six cruisers of the *Duke of Edinburgh* and *Warrior* classes the mean result was 2.1 pounds. The explanation is, of course, to be found in the fact that while in the *Duke of Edinburgh* the water consumption per unit of power developed by the main engines averaged 19 pounds, the consumption for the *Invincibles* was about 13 pounds. At lower power, however, the results are not quite so favorable. At what is regarded as the continuous-

Table II.—TRIALS OF A TURBINE TORPEDO-BOAT DESTROYER IN 1908.

Name of vessel.	Type of vessel.	Builders of vessel and makers of machinery.	Speed on 6 hours' run.
Amazon....	Torpedo-boat destroyer.	Messrs. Thornycroft & Co.	33.2 knots.

Table III.—TRIALS OF FIRST-CLASS TURBINE-DRIVEN TORPEDO BOATS IN 1908.

Name of vessel.	Type of vessel.	Builders of vessel and makers of machinery.	Speed on 6 hours' run.
			knots.
No. 13.....	Torpedo-boat.	Messrs. J. S. White & Co.....	26.4
No. 14.....	do.	Messrs. J. S. White & Co.....	26 6
No. 15	do.	Messrs. J. S. White & Co.....	26 5
No. 17.....	do.	Messrs. Denny, of Dumbarton....	26.2
No. 18.....	do.	Messrs. Denny, of Dumbarton....	26.2
No. 19.....	do.	Messrs. Thornycroft..	26 2
No. 20.....	do.	Messrs. Thornycroft.....	26.5
No. 21.....	do.	Messrs. Hawthorn, Leslie & Co.	26.2
No. 25.....	do.	Messrs. J. S. White & Co.....	26.2
No. 29.....	do.	Messrs. Denny, of Dumbarton....	26.2
No. 30.....	do.	Messrs. Denny, of Dumbarton....	26.0
No. 31.....	do.	Messrs. Thornycroft.....	26 4
No. 16.....	do.	Messrs. J. S. White & Co.....	26.5

cruising speed, when the *Invincibles* developed from 29,000 to 31,000 horsepower, the mean consumption was rather under 1.7 pounds. In the case of the *Minotaur* trio the mean result was slightly higher—1.76 pounds of coal per indicated horsepower—whereas in the six vessels of the *Duke of Edinburgh* class the mean was 1.95 pounds. At about one-fifth power the mean result for the three *Invincible* cruisers was 2.4 pounds,

whereas in the case of the *Minotaur* trio the mean was 1.87 pounds, and in the six vessels of the *Duke of Edinburgh* class it was 2.05 pounds, so that here, as in all cases, it is found that at low power the turbine is not so economical as the reciprocating engine. The *Minotaur* trio attained the designed speed of 23 knots, whilst the cruisers of the *Invincible* class, designed for 25 knots, proved themselves capable of 26 knots. The speed of the ships varied considerably, as a consequence of the adoption of different types of propellers, and no doubt opportunity will be taken at an early date of utilizing the experience gained with all three ships, in order to adopt the screw the proportions of which are found to be the most satisfactory.

In Table II are given the trial results of the only torpedo-boat destroyer put through her paces during the year. In this case the legend speed was 33 knots, and on the six hours' run the actual rate was 33.2 knots. Four vessels of this class were tried in the preceding year, when the speeds varied between 35.67 and 34.5 knots, so that we have now in the service five vessels capable of maintaining 33 knots in favorable weather. The view, however, is entertained that it is better to make provision for heavy weather, and the new vessels to be built are to be made more seaworthy even at the expense of speed. Thirteen torpedo boats have passed through their trial. These were originally regarded as coastal destroyers, but they have been more fitly classified later as torpedo boats. Their displacement tonnage ranges from 240 to 270 tons, and their length from 172 feet to 185 feet. With turbine machinery of 4,000 indicated horsepower, the contractors were required to guarantee a speed of 26 knots; and it will be seen that in the thirteen instances this has been achieved on the six hours' run. As with their destroyers, Messrs. White, of Cowes, have been especially successful with torpedo boats, their speed averaging 26½ knots. Messrs. Thornycroft have also succeeded in averaging over 26¼ knots, and in most other instances the rate was 26.2 knots. The conditions as to load and oil consumption were severe, and the Admiralty and the contractors alike are to be congratulated on the results.—"Engineering."

TURBINES AS DISCUSSED BY THE GERMAN INSTITUTION OF NAVAL ARCHITECTS.

The tenth general meeting of the German Institution of Naval Architects was opened on the 19th ult., in the Hall of the Konigl. Techn. Hochschule, under the presidency of the Grand Duke of Oldenburg.

The first paper on the list was one by Dr. G. Bauer, of the Vulcan Company, of Stettin, who called attention to the circumstance that the steam turbine had quite recently become recognized as a better engine than the reciprocating engine for nearly every kind of modern war vessel. This had first been established in the case of torpedo boats and then successively for small, swift cruisers, large cruisers and battleships. The credit for this surprisingly rapid development was due in the first place to Charles Algernon Parsons and the firms who worked out his system. Parsons' success had encouraged designers to make a trial of other turbine systems, and accordingly the turbines of Curtis and the A. E. G.—Allgemeine Elektricitäts-Gesellschaft—and later those of Zoelly and Schichau had been developed as engines for ships.

After reviewing the various types of marine turbines Dr. Bauer considered the methods of determining the power to be developed by a turbine for a given speed of vessel, one being that of finding the effective horsepower from the resistance offered by a towed model, and another that of comparison with the results attained with reciprocating engines under similar conditions. He made use of the latter method because it gave an opportunity of observing the peculiarities and relative applicability of the various turbine systems. Practically, the question to be answered was which system admitted of the highest propeller efficiency? Unfortunately, a high speed of revolution, which was advantageous for the turbine, was disadvantageous for the propeller. For torpedo boats it was now possible to design turbines that required a smaller degree of propeller efficiency than the corresponding reciprocating engines, while for other vessels the chance of attaining this state of

things was the greater the higher the speed and the lower the speed of revolution allowed by the particular turbine system. As soon, however, as a high speed of revolution was chosen, the power required for propulsion was considerably more with turbines than with reciprocating engines. Comparative results were then given between two cruisers differing only in the circumstance that the one had reciprocating engines and the other Parsons turbines. The turbine vessel required 22.7 per cent. more effective horsepower than the other for a given speed. A similar experiment was made a few years later with two other cruisers in which the one with Parsons turbines required 14 per cent. more E.H.P. at 24 knots and 7.5 per cent. at 14 knots than her rival. Meanwhile, comparative trials had been made between two cruisers driven by reciprocating engines and by Curtis turbines, respectively. In this case the result was reversed, the turbine cruiser requiring 11 per cent. less horsepower at a speed of 24 knots than that driven by reciprocating engines. In the case of two torpedo boats, again, the Curtis A. E. G. boat attained 2½ knots more than the reciprocating-engine boat under conditions otherwise the same for both. Dr. Bauer then gave particulars of the different cases, which went to show that where large additions had to be made to the E.H.P. for a given performance of the turbine vessel, either the speed of revolution of the engine was relatively very high, or the proportion borne by the disc area of the propellers to that of the midship section was very small, or, again, the number of propellers used, and therefore the complication of the after body of the vessel, was greater than in the case of the reciprocating engine. Such was in general the case with the Parsons system, while in the Curtis-A. E. G., Schichau and other systems with large turbine diameter, it was possible to employ a speed of revolution compatible with the use of relatively larger propellers.

In Germany the single-shaft system, that is, having the high and low-pressure turbines on the same shaft, was applied for the first time in the S. S. *Kaiser,* of the Hamburg-Amerika

Line, by the Vulcan, of Stettin, who now have a cruiser under construction on the system of the A. E. G.

Dr. Bauer emphasized the necessity of careful observation of the comparative results of turbine and reciprocating-engine vessels, and advocated the more frequent use of the torsion indicator.

Considering that high speed of revolution makes for economy, low weight and low cost in the turbine itself, but for loss of efficiency in the propeller, it becomes necessary in each case to effect a judicious compromise. To guide the designer in so doing, Dr. Bauer gave some results of investigations made by the Vulcan Company. It appeared that the fastest torpedo boats should have propellers with a maximum speed of tips of from 12,000 feet to 15,000 feet per minute, a minimum proportion of pitch to diameter of .95 to 1.1, and a maximum proportion of expanded area to projected area of 1.1 to 1.4. In battleships of 19 to 22 knots speed the corresponding figures were: 11,000 to 12,000, .8 to .9, .58 to .65, and .9 to .98, respectively. For intermediate conditions of speed, etc., the values lay between these extremes.

In regard to the weight of turbines as compared with that of reciprocating engines, it appeared that with high speed and suitable design the former may be as much as 15 or 16 per cent. the lighter of the two. At present the weights of Parsons and A. E. G. turbines are said to be about the same.

In regard to economy of steam at low speeds, Dr. Bauer showed that, while Parsons provided extra cruising-speed turbines, the A. E. G. system threw a number of the wheels out of gear by means of easily operated by-pass valves. In the latest designs in connection with the latter system the economy at the lower and higher speeds was the same.

Dr. Bauer alluded in passing to the expensive plant which the A. E. G. have laid down for testing the steam consumption and full powers of the turbines built by them. He also stated that careful investigation had lately been made as to the steam required by the auxiliary machinery. The extra steam required by these was from 10 to 15 per cent. with reciprocating engines, and from 15 to 17 per cent. with turbines.

After discussing at some length the question of the superheating of the steam, which in a case cited gave an economy of 9.24 per cent. in coal, Dr. Bauer came to the conclusion that the gain to be obtained by it was greater for the A. E. G. system than for that of Parsons.

In regard to going astern, it was next shown how, with given steam pressure, the power for going astern might be suitably regulated by the use of nozzles with smaller section than those for going ahead; and, further, that the power required to stop a vessel within a certain time might be determined with sufficient accuracy by the application of the ordinary mechanical principles, when the sternward thrust of the propeller and the resistance of the vessel herself were separately taken into consideration. In a recently tried torpedo boat with A. E. G.-Curtis turbine the stopping time had been less than that of a sister vessel with reciprocating engines. Large propellers were better than small ones for stopping.

Comparisons made between single-shaft turbines and those of Parsons with more than one shaft showed the greater simplicity of the general arrangement of the former and the greater facility with which the engine room could be subdivided by bulkheads.

A drawback to the four-shaft Parsons arrangement was shown to lie in the circumstance that at cruising speed all the shafts were turning, whereas in the corresponding A. E. G. arrangement two of the shafts were not at work, and their turbines could then be overhauled. In the course of a discussion of the complication produced by a multiplication of shafts and propellers, the fact was mentioned that the introduction of a casing tube between the point of exit and the propeller boss of a torpedo boat had increased the speed of the latter by .38 of a knot.

In regard to accidents that had hitherto happened with Parsons turbines, it was stated that these had in nearly all cases been in connection with the blades which were more numerous on this method than in that of the A. E. G., while they were at the same time weaker and had less clearance. It was con-

sidered that such accidents were with the latter system less likely to happen.

Mention was finally made of applications of the single-shaft Curtis system in America, and of one such now being made by the firm of John Brown, of Glasgow, for the British Admiralty.

The discussion on Dr. Bauer's paper was opened by Admiral v. Eichstedt, who recalled the circumstance that he had two years ago reviewed the considerations by which the Reichsmarine-Amt—Imperial Navy Office—would be guided in considering the question of the introduction of the turbine as an engine for war vessels. These were: (1) That the speed of revolution be considerably reduced; (2) that it was very important that the engines of battleships which had to maneuver together in fleets should all be alike; (3) that the Reichsmarine-Amt could not bind themselves to any one of the rival systems, because improvements were to be looked for in all of them. The Reichsmarine-Amt had since then proceeded on these lines, and had given the opportunity of testing and developing the different systems in connection with the construction of torpedo boats and small cruisers. For large cruisers orders had been placed for Parsons turbines, while for battleships the reciprocating engine had been adhered to. The author had said that the time had now arrived for the application of the turbine to battleships as well, and had shown that this engine was now able to meet all requirements. The personal opinions of the speaker coincided with those expressed by the author on all points, and he would like to enforce the fact that the total performance was in every case improved by the lowering of the speed of revolution, for, although the efficiency of the turbines was reduced thereby, the axial thrust of the propellers was increased in a much greater ratio. It might be deemed advisable to await the results to be obtained with the small cruisers under construction before proceeding to place turbines in battleships. But he would not like to wait so long; for they had experience with torpedo boats which went to show that low-speeded turbines might be fairly relied on to give good

results in battleships. In the coming year tenders would be invited for battleships for a second squadron, and as it was important that the vessels of the latter should all be alike, *i.e.*, either all with reciprocating engines or all with turbines, the question could, in view of the paper just read and of the experience obtained, already be decided in favor of the turbines. The question thus, in the Admiral's opinion, entered on an entirely new phase. The engineers could supply the turbines themselves, and the question now to be answered was, which was the best system for German needs. After an extensive investigation of the subject the author was in favor of having the turbines on a single shaft, not the high-pressure and low-pressure on different shafts. They were in face of the necessity for providing a type of machinery for a squadron, and all the vessels of that squadron must, therefore, be provided with single-shaft engines. They had to consider whether the vessels were to be of the three-propeller or of the four-propeller type. In connection with this he unhesitatingly advocated the three-turbine vessels recommended by Dr. Bauer. This was not the place for the consideration in detail of all the advantages of the three-propeller and four-propeller systems, but he wished to point out that all the German battleships were of the first-named type and had great maneuvering power. Moreover, for maneuvers in close order the four propellers were liable to damage, and furthermore all the German naval officers were used to the three-propeller system, and in view of the transferences of officers from one vessel to another it would be disadvantageous to bring in the four-propeller system as well. Indeed, the whole arrangement of a battleship favored the triple system. The heavy guns required longitudinal bulkheads for their support, so that the after part of the vessel had to be divided into three sections. The German Navy owed much to the Parsons turbine, and it seemed ungrateful to give it up; but opportunity had been afforded to its advocates on a fairly large scale of showing what it could do and of gathering further experience; and again, it was not impossible that the Parsons turbine builders would also adopt the single-shaft system and thus render

their engines suitable for battleship purposes. Indeed, he would be glad to give every system the opportunity of competing in battleships and in large cruisers also. It would then be found which of them was the most suitable for this type of vessel. In conclusion, he would like to return to the question of the use of turbines in cargo vessels, and to express the wish that this might become possible. He believed that here also important advantages would show themselves, especially if the change were accompanied by the introduction of the well-tried water-tube boiler of the Navy.

Geheimer Regierungsrat Professor Flamm observed that the author had in several places laid stress upon the importance of reducing the speed of revolution of the propeller in order to increase efficiency. On the ground of observations with model propellers in a tank, he wished to draw attention to the probability that a not unimportant increase in the speed of revolution of the propeller without loss of efficiency might be attained. Unfortunately, he could, as yet, only make this general statement in regard to the axial thrust. He had hitherto been unable to make exact measurements as to the degree of efficiency for want of the necessary apparatus. He wished to supplement his remarks of last year by the statement that the idea that the propeller always scattered the water in a radial direction was erroneous; on the contrary, the tendency was for it to suck towards the center. The axial thrust increased with the speed of revolution, and he was prepared to demonstrate this experimentally at any time. He wished to call attention to the circumstance that the air which found its way into the propeller as a result of the suction in question might reduce its efficiency. He had made numerous experiments which went to show that at the instant when a stream of air obtained access to the propeller, the latter at once lost its axial effect altogether. The speaker made this clear by pictures thrown upon the screen showing in a still more pronounced manner the effects illustrated in the Supplement to "The Engineer" of April 3d of this year. He had covered the surface of the water with a thin wooden board to keep out the air. The effect was astonishing.

Propellers, which before this had been inefficient foam raisers, suddenly gave a very good axial thrust. He believed, therefore, that it was right and feasible to increase the speed of revolution of the propeller, and thereby to do away with the present speed compromise between it and the turbine. Referring to the propeller running at 2,000 to 3,600 revolutions shown on the screen, he said it was clearly observable that it exercised a sucking—never a dispersing—tendency upon the surrounding water.

Herr Boveri said he had heard with satisfaction the view expressed by Dr. Bauer at the beginning of his paper, that steam turbines could now be definitely accepted as the engines best suited for war vessels; in this the author had endorsed the opinions that he had himself expressed in the same place two years ago. Since Dr. Bauer could only have founded this opinion on the practical performances of vessels fitted with Parsons engines, he was justified in concluding that the various unfavorable opinions passed by him on the Parsons turbine were not meant to be taken too seriously. He would not, therefore, dwell very long upon them, but would confine himself to refuting the assertion that the future belonged to the single-shaft turbine sets. From an academical point of view, the idea might be right, but practically it could be accepted only in so far as it was supported by actual practice, and this gave a materially different result. In regard to the distribution over two shafts, the author had started from incorrect premises and had made the little joke of drawing a very long Parsons turbine and then inferring that the additional shaft was rendered necessary by this excess of length alone. This view was incorrect. The reason for putting turbines on more than one shaft lay in the better effect thereby attained, and the author had himself supplied particulars which showed this. He had said that the efficiency of the turbine was the better the greater the power developed and the greater the speed of revolution. If, for instance, in a torpedo boat with a total output of 12,000 indicated horsepower the installation consisted of single-shaft turbines, this meant two engines of 6,000 indicated horsepower

each. If, however, the power were distributed on the Parsons method there resulted, in effect, a single engine of 12,000 indicated horsepower. The comparison thus lay between the efficiencies of two 6,000 indicated horsepower engines on the one hand, and one 12,000 indicated horsepower engine on the other, and, according to the author's statement, the efficiency of the larger-powered engine was the better of the two. This improvement of the efficiency lay in the high-pressure part. With the Parsons turbine the boat would work with 800 revolutions, while with the two 6,000 indicated horsepower turbines it would work with 600. Here, also, then, the greater efficiency would, according to the statements of the author, lie with the Parsons turbine. With the cruisers the circumstances were somewhat different, but here also the higher efficiency was ensured by the greater power and higher speed of revolution attaching to the divided-shaft system. This was seen more clearly in the battleship installation of Parsons. Now, although the efficiency of the Parsons turbine might, as the author showed, be greater than that of the reciprocating engine, it might be objected that this was of no use unless we had propellers for it. In relation to this he wished to call attention to the circumstance that recent sets had already given evidence of the improvements effected in quickly running propellers. In S. M. S. *Stettin* these were considerably better than in S. M. S. *Lübeck,* and in *S. 137* they were still better. True, there was still much room for improvement in this respect, but he was convinced that careful experiments would effect considerable improvement, and that the general result would show to the advantage of the subdivided turbine. He had listened with pleasure to Professor Flamm's remarks with regard to high-speed propellers. The single-shaft arrangement, then, was a retrograde one, and not an improvement. The speaker believed that engineers had never given up high efficiencies in this way, but had always found means of overcoming difficulties which attached to them, and he ventured to assert that the obstacles to the Parsons system were now surmounted. In the latest ships they had achieved excellent results, which, as confirmed

by the Secretary of State, had won the full appreciation of the Imperial Navy. The cruising turbine had been made use of with the best results in a series of maneuvers following each other in rapid succession. He must repeat that the observations in regard to cruiser turbines were true of all turbine constructions, whether on the Parsons or on any other system. Everyone would have to adopt this expedient when reduced power had to be applied without loss of economy. The first sets were somewhat imperfect, but those of today were better. In conclusion, he could only repeat that he was unable to see an advantage in the single-shaft system, since the efficiency of the engine was reduced thereby, and this was the case in all turbines, on whatever system. He ventured to hope that on this question they would not run after the fashion too much. The single-shaft turbines were the fashion just now, but they had often seen that what was fashionable was not always the best.

Director Lasche, of the A. E. G. Company, said he would like to join issue with the last speaker on two points connected with two observations made by him, the one being that the single-shaft turbine had not yet proved its efficiency in practice, and the other that it was not easy to build a single-shaft turbine which would work with the same degree of efficiency as the Parsons turbine. He asserted that it was all the same to the Curtis turbine whether or not it had a larger quantity of steam to dispose of. His firm had made all sorts of investigations on a 6,000-horse engine of 600 tons in their shops, which were provided with all imaginable facilities for such work. The efficiency of the high-pressure part was already so good that a larger supply of steam would be able to improve it to a very small degree only, and a further increase of that of the low-pressure part was not possible, since it was so designed that the supply of steam could only just pass through it. When they had begun the construction of these engines some years previously, their aim was to create the single-shaft turbine, and the question had only to be decided whether they could attain the same result for a given quantity of steam with them as

with the complicated Parsons turbines. They had proved this in torpedo boats, and would shortly do the same in the case of a cruiser.

In replying, Dr. Bauer said that Director Lasche had shown that the efficiency of properly designed single-shaft turbines was the same as that of the Parsons turbine. He need not, therefore, discuss Herr Boveri's objections further than in emphasizing that the simplest turbine system is the best for war vessels, for in these simplicity is of the first importance. If, then, they succeeded in producing a simple steam turbine with the same consumption as the Parsons turbine, he did not know what reasons there could be for keeping to the complicated Parsons method and not adopting the improvement.

The Grand Duke of Oldenburg said the author had made them acquainted with the new turbine installation in a very interesting manner. The paper was of the more importance that it was based on actual practice, and upheld what was probably the most prevalent view there—that the single-shaft system was the most advantageous.—"The Engineer," Dec. 4, 1908.

TURBINE PROPELLERS.

The extraordinary change that has taken place in recent years in the proportions of screw propellers for turbine steamers compared with those adopted for reciprocating-engine vessels is about to be accentuated by an experiment that is being tried on the Cunard Liner *Mauretania*. When this vessel ran her trials she was fitted with four three-bladed propellers 17 feet in diameter by about 16 feet pitch, and she attained about 26 knots with 190 revolutions and 78,000 shaft horsepower. Some months ago the outer propeller on the port shaft lost two blades owing to the securing studs breaking off, and more recently the inside starboard propeller was also badly damaged. Whatever the practical success of the two mammoth Cunarders may have been, there is no doubt that both vessels suffered considerably from vibration, and this arose almost entirely from

the wing propellers. The screws were modified long ago in the *Lusitania;* the diameter was reduced in order to obtain a greater clearance between the tips of the blades and the hull of the ship; but it is only just recently during her annual overhaul that a change has been made in those of the *Mauretania.* Propellers of the original dimensions are being retained on the two inner shafts, but four-bladed screws have been fitted on the two outer shafts. The proportions of pitch, surface and diameter are similar to those of the original screws, but the shape of the blades has been altered considerably. Hitherto almost every turbine propeller has been oval or circular; and whether wide at the tip or purely elliptical, it has had the area distributed symmetrically on each side of the center line of the blade. Nearly all have been three-bladed. The *Victorian* commenced her career with four-bladed screws, but they have not been adopted in any other turbine vessel save for occasional experimental trials, and those of the *Victorian* have now been altered to three blades. The change is being made more from the point of view of modifying the vibration than from propulsive considerations, but it is the latter which calls for attention. Additional facts bearing on the efficiency of turbine propellers are being eagerly sought for, and in this case the change should afford data of more than ordinary interest. The new screws are cast solid instead of having blades secured to the boss; they possess to a much greater degree than we have yet seen in turbine steamers the characteristics of a tramp-steamer propeller, especially from the point of view of shape of blade. How such a type with the narrow blades common to the latter style of practice will operate at turbine revolutions remains to be seen. Not a few marine engineers believe the *Mauretania* and *Lusitania* to be fitted with larger propellers than are really necessary. Both slip ratio and thrust per square foot of blade area were very low on trial even at the highest speed. Naturally, in a seaway, when the same power is being developed and the ship is retarded by the weather, both these items are considerably increased, but even then they are low compared with other turbine steamers, and it is considered highly probable

that slightly smaller propellers, which would possess the additional advantage of running faster, would be more efficient in smooth water, and, owing to their increased clearance from the hull, would not cause as much vibration as the original screws did.

At the last meeting of the Naval Architects Mr. R. E. Froude read a paper of particular value on the efficiency of propellers as deduced from model experiments. The main fact to be gleaned from his admirably compiled curves is that within very wide limits of pitch ratio the efficiency of propellers with a standard shape of blade falls off proportionally much less rapidly with reduction of pitch ratio than for a standard pitch ratio it decreases with increase of area ratio, more particularly when the ratio of area to disc exceeds about 70 per cent. In other words, the practical designer is apt to be more correct if he adopts a large diameter in association with a medium area ratio and fine pitch ratio than if his area ratio is very big and his pitch ratio coarse. It is in absolute size and not in proportion that the Cunarders' propellers are thought to be too large, and with those figures of Mr. Froude's in our mind we cannot help hoping that in the interests of the profession any further changes will be systematic, so that we may get additional corroboration of model experiments from actual practice. So far, the trials of numerous other vessels have proved the accuracy of the above theory. The propellers used on the coastal destroyers, which may be said practically to represent the present minimum size of turbine propeller, differ considerably in proportions on the various ships. The turbines are the same in nearly all cases, but estimates of the relative efficiencies of the propellers are impossible owing to the lack of space available for fitting torsion meters. In one or two cases, however, similar ships were tried with different propellers; but even then, whatever the speed results may have been, the efficiency was still unobtainable. In some of these vessels very exaggerated area ratios have been adopted; in others it has been quite moderate, but neither can, we fancy, be as favorable from the propulsive point of view as they might be. The value of the data

given by Mr. Froude is, so far, hardly appreciated at its full value; but it gives cause for reflection as to the scope apparently available for improvement in turbine propeller efficiency. The propellers of the *Kaiser Wilhelm II* have an efficiency of B.H.P. ÷ E.H.P. of about 64 per cent., those of the *Lusitania* and *Dreadnought* about 48 per cent. If only half the difference were attained—and we cannot help thinking that it will be attained, though not, perhaps, this time in the case of the *Mauretania*—the average daily coal bill would be reduced by about 120 tons—say, from 900 to 780 in twenty-four hours, taking only the propelling machinery into account. The vessel is running at least 180 days out of the year—rather more, perhaps—say, 120 × 180 = 21,600 tons per annum, and for two ships = 43,200 tons of coal a year at, say, 14s. per ton average price, which represents a saving of over £30,000 a year to attain the same speed. On the other hand, the same shaft horsepower and consumption would, if used with a 56 per cent. propeller efficiency instead of 48 per cent., give 25.75 knots instead of 25. We take our basic figures from Mr. Bell's paper on the *Lusitania*. The efficiency suggested is good for turbine work, though not exceptional, but it is not one that would appeal to the owners of the *Kaiser Wilhelm* or *Deutschland*. An efficiency of even only 53 per cent. would reduce the coal bill nearly 10 per cent. With the saving possible it would appear to us a financially sound step to experiment with propellers of modified form with a view to increasing the efficiency. For propellers of 17 feet diameter running at 180 to 190 revolutions, 48 per cent. efficiency strikes us as being ridiculously small. The efficiency in the case of the propellers of the later County class, which were only about 12 inches less in diameter and which revolved at nearly 150 revolutions, was well over 60 per cent., and it is difficult, indeed, to believe that the lower figure cannot be improved.

Much as Englishmen are gratified at the success of the Cunard Line, propeller efficiency in their case is merely a financial matter, but it is a national one in the case of the *Dreadnoughts*. Instead of 21¼ knots on trial, the same higher per-

formance we have suggested for the *Lusitania's* screws would give over 22. We do not suppose that the *Dreadnought* is much less superior relatively to the *Nassau* or *Voltaire,* because she is only two knots faster and not three, but the odd knot might be useful, and if it is obtainable at a reasonable cost it is the duty of the Admiralty engineering staff to see that it is done. They are presumably more alive to that fact than other people, and from the new vessels of the class we anticipate that valuable information on turbine propellers will be obtained. There is nevertheless as much financial saving to be made by foresight as there is by experience, but with few exceptions propellers have not received the amount of practical scientific attention with the view to ultimate advantages that the turbine itself has. There is neither the time, nor, as a rule, the inclination to spend more money on a ship when once she has fulfilled the contract conditions, although it is often surmised that a change in propellers would conduce to better performance; on the other hand, the conditions are occasionally such that it is not worth while to attempt it. But from the taxpayer's point of view improvement in propeller performance for naval vessels is even more essential now than it was in the time of the *Good Hope* and County classes, while the data available for design is not as copious, owing to the radical change in conditions. The theoretical saving that appears attainable in the case of the Cunarders is considerable from the absolute standpoint, greatly outweighing the cost of the experiment, and should this eventually be undertaken and prove successful it will afford additional proof that "overscrewing" is nearly as disadvantageous as "underscrewing," not only as it was in the time of the *Iris,* but also at the present day.—"The Engineer," Jan. 15, 1909.

THE RACE OF THE TURBINES.

Now that the Government has sanctioned the installation of the Cramp-Zoelly system of marine turbines in the new torpedo-boat destroyers *Mayrant* and *Warrington,* building at the

plant of the Wm. Cramp & Sons Ship and Engine Building Co., Philadelphia, and the utilization of not only the Parsons and the Curtis types in other vessels, the abandonment of the reciprocating engine as a propelling agency in all naval vessels to be contracted for in future and the adoption of this modern form of marine machinery, is certain to bring about great competition among builders of the various types. It is significant that while Great Britain has practically adopted the Parsons turbine for all new vessels, the United States is using not only this tried and successful type, but is encouraging builders to develop other styles.

The Parsons type of turbine has given such satisfaction that it will not be easy to displace it in the estimation of marine engineers. In the British Navy especially it continues to show innumerable advantages over the reciprocating engine, and especially so in the case of low percentage of coal consumption. Some figures on the steam trials of six of the newest battleships and armored cruisers, two of which, a battleship and a cruiser, were fitted with reciprocating machinery and the other four with Parsons turbines, appear in the January 1 issue of "Engineering," with honors on the side of the turbine. At full power the four turbine-propelled ships showed an average rate of less than 1.5 pounds of coal per horsepower hour. One of these vessels, the *Indomitable,* returned the remarkably low rate of 1.2 pounds, including the fuel used for running the auxiliary plant. As a contrast to this the two reciprocating-engine ships averaged 1.9 pounds. Says "Engineering":

"The mean result for the three cruisers of the *Invincible* class is under 1.5 pounds, whereas in the case of the three cruisers of the immediately preceding class—the *Minotaur* trio—the average consumption at full power was 1.8 pounds, and in the six cruisers of the *Duke of Edinburgh* and *Warrior* classes the mean result was 2.1 pounds. The explanation is, of course, to be found in the fact that while in the *Duke of Edinburgh* the water consumption per unit of power developed by the main engines averaged 19 pounds, the consumption for the *Invincibles* was about 13 pounds. At lower power, however, the

results are not quite so favorable. At what is regarded as the continuous-cruising speed, when the *Invincibles* developed from 29,000 to 31,000 horsepower, the mean consumption was rather under 1.7 pounds. In the case of the *Minotaur* trio the mean result was slightly higher—1.76 pounds of coal per indicated horsepower—whereas in the six vessels of the *Duke of Edinburgh* class the mean was 1.95 pounds. At about one-fifth power the mean result for the three *Invincible* cruisers was 2.4 pounds, whereas in the case of the *Minotaur* trio the mean was 1.87 pounds, and in the six vessels of the *Duke of Edinburgh* class it was 2.05 pounds, so that here, as in all cases, it is found that at lower power the turbine is not so economical as the reciprocating engine. The *Minotaur* trio attained the designed speed of 23 knots, whilst the cruisers of the *Invincible* class, designed for 25 knots, proved themselves capable of 26 knots. The speed of the ships varied considerably, as a consequence of the adoption of different types of propellers, and no doubt opportunity will be taken at an early date of utilizing the experience gained with all three ships, in order to adopt the screw the proportions of which are found to be the most satisfactory."

As has been brought out in these tests, the turbine at the present stage of its development is only economical when utilized in high-speed ships, and for this class of vessel it appears to be the ideal form of propulsion. Whether it can be so improved as to make it applicable to slow freight steamers is a problem for the designers, and it is likely that the next few years will see many such tests, since a fortune lies in the way of the builder of an economical slow-speed turbine. In the meantime, the United States is doing her share in the development of this useful new form of marine engine.—"The Nautical Gazette."

TURBINE VERSUS RECIPROCATING ENGINES.

Both in Germany and the United States papers have recently been read to the respective Institutions of Naval Architects on the subject of steam turbines for marine work, and both at

Berlin and New York we have been favored with representative technical views on the question. The paper read by Dr. Bauer, of the famous Vulcan Company at Stettin, last November, of which an abstract appeared in "The Engineer" of December 4th, has attracted general interest in marine engineering circles, as it was remarkable for admitting—some might even say claiming—the superiority of the turbine over the reciprocating engine. In this country, where marine engineering is a very important trade, the question cropped up and was answered some years ago; but in Germany the turbine system of propulsion has, until recently, met with such abnormally hostile criticism that it is really interesting to note the opinion of one of the leading German marine engineers that the problem of the most suitable type of propelling machinery is now only as to the best type of turbine to use, the reciprocating system being entirely ignored. The views set forth by the chief engineer of the Maschinenbau Vulcan Stettin Aktien-Gesellschaft are entitled to full consideration, and much interest attaches to the comparative data he publishes in regard to ships built at Stettin with different systems of machinery. But with other information to guide us we cannot admit that we are yet convinced of the superiority of the independent-impulse turbine system that he advocates so strongly; however, we shall no doubt be favored with further results as the vessels now being built with this type of turbine are completed, more especially as the intention of the Admiralty is to depart from the Parsons type of turbine in one of the new *Bellona* class of cruisers, and sound comparative results should be available.

The relative trial performances of the two cruisers to which Dr. Bauer refers—the *Lubeck* (turbine) and the *Hamburg* (reciprocating) did not bear out the superiority of the Parsons turbine to anything like the extent that the *Amethyst* did in her trials against the *Topaze,* but the machinery of the *Hamburg,* which is of little more power, is very considerably heavier than that of the *Topaze,* and far more has been made of the greater weight to secure exceptional economy. While the piston engine was certainly better at low powers on trial, the turbine vessel

was afterwards found in service to be by far the more economical, even at low speeds, and Dr. Bauer is not giving us all the facts when he talks about the turbine vessel requiring 22 per cent. more horsepower for the same speed as the sister ship. A great many more turbine vessels have been built in this country than in Germany, and we have more accurate data at our command than this. The facts are that with 11,000 brake horsepower the *Hamburg* attained 23.15 knots in deep water—a suitable speed for the depth. With hull and boilers to the same drawings, the *Lubeck* attained 23.16 knots with 14,158 brake horsepower. With practically the same steam consumption much more shaft horsepower was developed by the turbine, but was lost by the propeller, the overall efficiency being practically the same. When comparisons unfavorable to the turbine are required, the trial results of the *Lubeck* in shallow water—22.55 knots with 13,880 horsepower—are generally quoted. When, however, Dr. Bauer wishes to compare the Curtis type of turbine, he does so with a reciprocating ship, and instances the case of the German destroyers built at the Vulcan Works, and of which the Curtis vessel proved 2½ knots faster. He ignores the fact that the Parsons vessel of the same class was nearly a knot faster still, and states that the weights of the two systems are the same, regardless of the fact that in the only similar types of ship that are yet completed, in the case of the *Salem* (Curtis) and the *Chester* (Parsons) the respective weights for turbines only were 204 tons, against 155, and in the case of the German destroyers the excess was nearly as much proportionately.

The true deduction to be made from Dr. Bauer's paper is not so apparent as it might be. When turbine propulsion first came up the system was roundly condemned in Germany. By degrees the salient advantages were found to be commercially profitable or to add to military efficiency in warships. But concurrently with this growing appreciation of the value of the marine turbine, which was then invariably of the Parsons type, there has developed, first on the Continent, and now in this country, a much more favorable view of impulse turbine sys-

tems generally. That machines on this principle, developed especially by Zoelly, Rateau, with his own machines, and the A. E. G. Co., which makes the Curtis type, are making immense headway at present is very apparent on land, where in some ways they possess considerable advantages over the Parsons type. For marine work, however, little has been done except in about half a dozen cases. The great advantage claimed by Bauer for the impulse type which he advocates is the fact that it can be used in single units requiring only one shaft. In other words, a twin-screw turbine-driven vessel can be made with two complete and independent reversing turbines, one for each shaft. Such an arrangement is undoubtedly a highly attractive one on paper, and that some arrangement of the kind will eventually be tried there is little doubt. Designs exist in more than one drawing office for vessels driven by twin screws and turbines, but at present only the American cruiser and one merchant steamer, one German destroyer and one Channel steamer exist with such an arrangement, though about a dozen more are in course of construction. Unwilling to take up a system that has been so generally abused in their country, German marine engineers, with the exception of one eminent firm, are now striving to make pure impulse turbines suitable for ship propulsion, but it is very doubtful if the disc construction that is almost mechanically essential in this type can compete in weight with the drum type that has to be adopted by Parsons, and its efficiency has certainly not yet been shown to equal it. Something may be done by combining the two systems, the impulse portion for the high-pressure, and the Parsons for the low-pressure, as was done by the Westinghouse Company, but we are not by any means convinced of the suitability of the types advocated by Dr. Bauer.

We should be more indebted to many writers on this question of marine machinery if they would give us the facts of the reciprocating engine vessel's performance as well when making comparisons. It is useless to point out that a turbine vessel exceeded the speed of the other ship, or burnt less coal, unless we know the conditions for both vessels. In the case

of the American scouts, all the available comparative data were given, and, in addition, liberal drawings and photographs were published. The results possess much interest, and are capable of fair analysis and deduction, but we doubt whether a gathering of technical men will be altogether convinced as to the advantages of the A. E. G. turbine simply from Dr. Bauer's paper. A few calculations and a sketch design in sectional elevation will show at once the inherent mechanical difficulties in the way of placing one complete and independent reversing-impulse turbine on each shaft of a twin-screw vessel—that is, if economy is the object. The general arrangement, however, is so attractive that a great deal of time will undoubtedly be devoted to removing the existing objections.—"The Engineer."

TURBINES AND PROPELLERS.

SIR:—I read with great interest the leading article dealing with the application of the steam turbine to slow-speed steamers which appeared in your issue of the 16th, and would be pleased if you would allow me to add a few remarks.

In the first place, what advantages are to be gained by the adoption of the turbine in this class of vessel? It must be remembered that the modern triple and quadruple-expansion engines fitted to the ordinary cargo tramps are highly economical machines, and that the turbine at its best cannot compare so favorably with this class of machinery as it does with the reciprocating engines of high-speed vessels where economy must necessarily be sacrificed to weight. It is doubtful whether there would be any saving in space, while absence of vibration is of no importance in this case.

As regards attention, the adoption of the turbine would have little effect in reducing the engine-room staff, as the ordinary slow-speed tramp engine requires and receives very little attention when running. The reciprocating engine is thoroughly understood, and even the most extensive breakdown can be repaired, while with the turbine, a blading strip may take

place, which it would be difficult, if not impossible, to repair at sea. This might be a very serious matter for a tramp steamer, which very often would be far away from the shipping tracks. I have made no mention of weight, but propose to deal with it in connection with the propeller end of the combination on which it is largely dependent.

The above remarks have been made on the assumption that turbines could be fitted, and without reference to the propeller question at all, and without any consideration of the difficulties in the way.

Let us now consider some of these difficulties. Mr. James Denny in his paper gives as an example the case of a vessel of 22 knots speed and 10,000 horsepower, with turbines running at 700 revolutions per minute, and points out that for a vessel of the same power at 12 knots the revolutions per minute would be limited to 110. Mr. Denny infers from this that, owing to the heavier turbines and increased leakage loss, the application of turbine propulsion cannot be so advantageous at the lower speed.

In the article it is asked why the revolutions should be limited to 110 per minute, and, taking the case of the 22-knot ship, it is pointed out that the revolutions would be about 350 per minute at 12 knots. To quote the article: "The efficiency of the turbines would certainly be much smaller, but this would be mainly the result of the fact that the machine would be too large." Now, suppose we take up this example where it is left off in the article and go into the case a little more fully.

Considering the turbines only for the present. It is admitted in the article that the efficiency is low, and as we are to compete with the most efficient reciprocating engines it must necessarily be improved. What are the reasons for the low efficiency? In the first place, the turbines are considerably under-speeded, and in the second the steam pressure at the high-pressure turbine would be only about 10 pounds to 15 pounds per square inch, so that only a proportion of the available heat energy in the steam is being expended in useful work.

Obviously, then, we must increase the speed of the turbine

blades, and adapt the turbine to take the full pressure of steam. If the speed of the blades is to be the same as it was at 700 revolutions per minute, then the diameter of the turbine drums must be doubled, thus making the turbines about four times their original weight.

Now a vessel requiring 10,000 horsepower at 22 knots would only need about, say, 1,500 horsepower at 12 knots, so that as the turbine drums are twice their original diameter the height of the blades would be roughly about one-twelfth of their original height. In addition, the tip clearances would have to be increased on account of the doubled drum diameter.

Thus in attempting to improve the turbine efficiency, although the horsepower is only about one-sixth of the original, we have had to increase the weight four times, and to adopt such a ratio of blade height to drum diameter as enormously to increase the leakage loss. It must be admitted, I think, that this fully bears out Mr. James Denny's contention.

Now to turn to the propeller. It must be remembered that the propellers of the 22-knot vessel would be running at an apparent slip of about 20 to 25 per cent., and it is doubtful if the slip would be much reduced, if at all, at the lower speed. Now the efficiency of these screws, although not high, is fairly satisfactory when working behind a ship with the fine form necessary for 22-knot speed. If, however, the ship is a bluff 12-knot cargo tramp, with a block coefficient of .78 and a 20 per cent. wake, then the efficiency of these screws running at a real slip of over 40 per cent.—as they would be—is a very doubtful quantity. However, a much more convincing argument is to take an actual example. Suppose we consider the application of turbines to a typical cargo tramp steamer with a block coefficient of .77, to attain a speed of 12 knots on trial with a 3,600 horsepower. The triple-expansion engines for this vessel would run at 75 revolutions per minute, and the weight of the main engines, condenser and pumps would not be more than 160 tons, without shafting and auxiliaries.

Turning to the turbines. If the revolutions be 350 per minute, and we adopt the low drum speed of 80 feet per second,

the diameter of the high-pressure turbine drum would be 52 inches and the low-pressure about 73 inches, and the height of the first row of blades about nine-sixteenths inch. The usual triple-shaft arrangement is assumed. The weight of these turbines with all fittings, condensers, air pumps, lubricating gear, etc., would be about 200 tons.

Thus if we assume that the difference of weight between the turbine and reciprocating machinery to be equalized by the stern gear—the turbines must run at 350 revolutions per minute if their weight is to compare with that of the reciprocating engines. Now let us see what sort of propellers would be necessary to run at this speed.

The following table of alternative screws shows very clearly the effect of the low speed on the pitch:

Ratio $\frac{\text{Pitch}}{\text{Diameter}}$.	Diameter, feet.	Revolutions per minute.
1.0	13.2	99
0.3	10.16	162
0.6	7.65	287
0.55	6.94	344

The propellers are all calculated for the same apparent slip—about 7.5 per cent.—and it will be seen that to obtain 350 revolutions per minute we should have to adopt screws with the extraordinary pitch ratio of something less than .55.

The highest rate of revolution that could reasonably be adopted would be about 160, with a pitch ratio of .8, and, of course, at this speed the weight of the turbines and the enormous leakage loss would render the design impracticable. It would seem, therefore, that the problem of adapting turbines to slow-speed vessels is capable of no easy solution.

It is very probable that in course of time the turbine will be adopted to a much greater extent for medium-speed vessels, probably in combination with reciprocating engines, as the economy of the Parsons turbine when working with low pressures is certainly remarkable. However, at the lowest speeds with this combination, it becomes a question of balancing the gain in economy against the increase in weight.

It might perhaps—in view of the importance of weight—be an advantage in some cases to do away with the usual high-pressure turbine and substitute Curtis turbines. These turbines could be combined in the same casing with the usual low-pressure Parsons turbines and exhaust to them at about atmospheric pressure.— J. P. ANDERSON.

October 26th. —"The Engineer."

SOME EXHAUST STEAM TURBINE PLANTS.

A paper on "The Utilization of Exhaust Steam in Low-pressure Turbines" was recently brought before the Rugby Engineering Society by Mr. R. F. Halliwell, wherein the author makes a general review of the subject, and shows in a very conclusive manner the reason for the high efficiency of turbines as compared with reciprocating engines when dealing with steam of low pressure. Towards the end of the paper some representative examples of exhaust steam-turbine plants at present at work and of others which are being put down are given. Mention is first made of the plant at the Hallside works of the Steel Company of Scotland. This plant, which was put down in 1905, was the first in the British Isles to employ the modern type of Rateau accumulator. Steam is taken from cogging and finishing-mill engines and two or three small engines and steam hammers. It is delivered into an accumulator 11 feet 6 inches by 34 feet, the outlet from the accumulator being connected to two 450-kilowatt direct-current turbo generators exhausting into a condenser. In this way 900 kilowatts is obtained from steam which was formerly blown away into the atmosphere, as owing to the intermittent character of the load a satisfactory condensing plant would have been practically out of the question.

As an example of a mixed-pressure plant mention is made of an installation belonging to the Fife Coal Company, in which steam is collected from two winding engines, a fan engine, and several small pumps, and is delivered into a Rateau

accumulator 7 feet 6 inches by 30 feet. The amount of steam available for the turbine is only 16,000 pounds per hour, sufficient for about 400 kilowatts, and since the maximum normal load on the turbine is 750 kilowatts, the requisite amount of high-pressure steam to produce the additional load is admitted through groups of nozzles, as in ordinary Curtis high-pressure turbines. The maximum continuous output with high-pressure steam is about 900 kilowatts.

Naturally the author also calls attention to the scheme which is being developed in the North of England by Messrs. Merz & McLellan. This scheme, as is now fairly well known, consists of purchasing the exhaust steam from ironworks and similar concerns, and using it to run low-pressure turbines situated in small power stations adjacent to the works, the current being delivered into the network of mains in the northeast district, and the condensed steam being returned to the works. Willans & Robinson, Limited, have recently erected two 1,250-kilowatt low-pressure sets at the Newport works of Messrs. Samuelson, and the British Thomson-Houston Company has just completed a 1,500-kilowatt set for the Teesbridge Iron Works, to be supplied with steam from constantly running blowing engines, no accumulator being needed. The turbine will be connected to a surface condenser, by Messrs. Mirrlees Watson, of 7,800 square feet cooling surface, and will be fitted with a motor-operated synchronizing gear controlled from a substation some distance away.

As an example of exhaust-steam utilization in central station work, the plant of the power station of the Philadelphia Rapid Transit Company is given. This station contains four 1,500-horsepower and one 2,200-horsepower Corliss engines running non-condensing. Early in 1905 an 800-kilowatt Curtis low-pressure turbine was put down, and a second similar set at the beginning of 1906. The turbines are of the vertical type, running at 1,200 revolutions per minute, and they drive direct-current generators supplying current at 575 volts. The exhaust steam from one engine when delivering 1,150 kilowatts is sufficient to give an output from one turbine of 750 kilowatts with

a back pressure on the engine of one pound above the atmosphere. As about 86 kilowatts are required to operate the condensing plant, the net gain due to the use of the turbine is 664 kilowatts, equal to an increase in output of about 58 per cent. with the same amount of steam. As the maximum gain from running the engines condensing would not exceed 25 per cent., it is pointed out that the turbine ensures a gain of at least 26 per cent. over this arrangement. It should be mentioned that the turbines are not fitted with a governor, but as the leads from the turbine generators are connected to the engine-generator bus bars, if the turbine increases its speed or slows down load is taken off or put on the engine generators, thus reducing or increasing the amount of steam admitted to the system.

Further on in the paper the author states that "it may be urged that the saving due to applying exhaust turbines to non-condensing and inefficient engines is easily demonstrated, and while this is to some extent true, the fact that a considerable saving may be effected by applying exhaust turbines to condensing engines of the most economical type will be shown by the following example." The example taken is that of the Rapid Transit Company of New York. In the power station of this company a 5,000-kilowatt low-pressure turbine has been put down. Before it was decided to purchase the turbine an investigation was made by the chief engineer, Mr. H. G. Scott. The station in which the turbine is placed was designed for a capacity of more than 130,000 horsepower, and at present has eleven 7,500-horsepower double horizontal vertical Corliss engines. The engines have 42-inch high-pressure and 86-inch low-pressure cylinders by 60-inch stroke. The speed is 75 revolutions per minute.

An exhaustive series of tests was taken covering the operation of the engines at various loads, both condensing and non-condensing, and it was found that under condensing conditions the most economical load was 4,000 kilowatts, with a water rate of 17½ pounds per kilowatt. The operating loads are from 5,000 kilowatts to a maximum of 7,500 kilowatts, with an average water rate of 19 pounds per kilowatt. When run-

ning non-condensing, the maximum load is also 7,500 kilowatts, and with a total of 170,000 pounds of steam per hour, which is the proportion of the ultimate steaming capacity of the plant allocated to one engine, the engine will produce 7,300 kilowatts, giving a water rate of 23.3 pounds per kilowatt. The most economical load proved to be 5,750 kilowatts, with a water rate of 22.6 pounds per kilowatt. Tests were also taken to prove the quality of the steam exhausted from the engine, and showed that a deduction of about 7½ per cent. should be made from the total to give the amount available for the turbine. The turbine is of the Curtis vertical type, with three stages. It is mounted on a sub-base condenser containing 20,000 square feet cooling surface. The generator is of the induction type, and will deliver current to the same cables as the engine-driven generator without intervening switching apparatus. The combination will, therefore, be operated as a single unit, and no governor is required on the turbine except the emergency governor. At full load with 15 pounds to 16 pounds absolute initial pressure and 28½-inch vacuum, the water rate of the turbine is 29.7 pounds per kilowatt hour; consequently, when the engine is supplied with 170,000 pounds of steam per hour, with an output of 7,300 kilowatts, the turbine will deliver an additional 5,300 kilowatts, making a total of 12,600 kilowatts output from 170,000 pounds of steam, which gives a water rate of 13.5 pounds per kilowatt hour. It must be remembered, too, that this low consumption is obtained without superheat. In addition to the economy effected, the maximum output is raised from 7,500 kilowatts to 12,600 kilowatts with the available steam, an increase of 68 per cent.; this increase in capacity having been obtained at a cost of less than £6.25 per kilowatt. Assuming that the plant operates continuously, it is estimated that a saving of 1,660,000 pounds of feed-water per day will be effected, and this, with an evaporation of 8 pounds of water, means a saving of 93 tons of coal per day, sufficient with the prevailing cost of coal in New York, to pay for the cost of the turbine in little more than one year.—"The Engineer."

BOILER EFFICIENCY.

A very curious lecture—how curious will be realized presently—was delivered before the Junior Institution of Engineers by Dr. Nicolson, Professor of Mechanical Engineering in the University of Manchester, on the 14th instant. The lecture was on "The Laws of Heat Transmission in Steam Boilers as Deduced from Experiments." It will be remembered that some years ago Profesor Nicolson discovered, in conjunction with Professor Callendar, that engineers in the past had been all wrong about initial cylinder condensation, a thing which took place to only a small extent, the "missing quantity" going in valve leakage. He has now made another discovery still more important. It is that without exception all writers about boilers, designers of steam generators and physicists have been entirely mistaken in their interpretation of what goes on in the flue of a boiler. "What, it will be asked, of all the authorities from Péclet and Rankine to Bryan, Donkin and Kennedy, Longridge and Stromeyer, Isherwood, Gale and Kent, and many others, who have left professional opinion on this subject in the same settled state in which they found it, and have been quite satisfied to ignore any effect due to the velocity of gas flow which they might have been cognizant of, if indeed they believed in the existence of any such effect at all?"

It is, we confess, difficult to deal with a paper which contains a proposition so sweeping and so damaging to reputations as that which we have just quoted. It is almost needless to say that if it were made by one without authority and lacking the power to inculcate erroneous views, we should have passed it by without comment; but a lecture by Dr. Nicolson deserves careful examination. Our examination results in the conclusion that Dr. Nicolson is mistaken from first to last, and that his lecture is full of fallacies. The general thesis is very easily stated. The fire side of flue is not as much hotter than the water side as it ought to be, because the products of combustion pass so slowly over it that films of cold gas adhere to the plate. If, now, we make the gas move fast enough, then

these cool films will be swept away, and the heat interchange will be so facilitated that a square foot of boiler surface may be made at least one hundred times as efficient as it is now. In other words, an evaporation of about 1,000 pounds per square foot of heating surface per hour is conceivable. There are two ways in which this staggering proposition may be considered. In the first place it may be said that the knowledge that cool layers of gas may adhere to plates is so far from being new that the fact has been carefully taken into consideration by Péclet. But leaving Péclet on one side, we may call Professor Nicolson's attention to the circumstance that Charles Wye Williams, more than seventy years ago, handled the whole subject in a very masterly treatise, and insisted on the absolute necessity of breaking up and mixing the products of combustion in order that every portion of them should have an opportunity of coming into contact with the boiler plates. Williams gives a diagram which is the precise counterpart of a diagram given by Professor Nicolson, to which we shall refer further presently. This diagram is a longitudinal and transverse section of a furnace tube, and shows by concentric circles how it is possible for the main body of the products of combustion to pass through the flue without ever coming into contact with the plates at all. Professor Nicolson's diagram shows the flue of a Cornish boiler in which a cylinder containing water is placed to prevent the passage of the products of combustion in solid columns, denounced by Wye Williams. Williams' treatises are now, unfortunately, very scarce, but Professor Nicolson will find a good deal quoted from him in Spon's Dictionary of Engineering, "Boilers," published in 1870. It is, however, quite unnecessary to labor the point. We have no hesitation in saying that all engineers of standing who have dealt with the generation of steam have preached the doctrine that the products of combustion should be broken up in order that every portion of them should be brought into contact with the plates, from the days of Seguin and the *Rocket* to this moment. The only novelty—if it be one—announced by Professor Nicolson is the statement that this end can best be secured by making the

gas travel at a high velocity over the heating surface. Now, in any given boiler the quantity of gas is limited and its velocity of flow will be fixed by the calorimeter of the boiler; that is to say, by the transverse area of the tubes or flues through which the gas has to pass on its way to the chimney. The resistance augments as we reduce the calorimeter. To overcome this draft must be increased, and so in the long run we come to a forced-draft boiler. Finally, Professor Nicolson's proposition means that with forced draft we get a larger output of steam than we do with natural draft. It will, we fear, be difficult to convince steam users that forced draft must be much better for them than natural draft.

Before dealing with Dr. Nicolson's experiments, we must consider the second step in his arguments. He takes a formula which is well known, expressing the rate at which heat flows through a plate: he shows that if the temperature of the two sides of a plate were, respectively, 1,500 degrees and 450 degrees, heat equivalent to the production of about 1,000 pounds of steam per hour per square foot would be possible. Fortunately, nothing like this can be realized in a boiler. The reason is, he says, that the gas in contact with the plate is less in temperature than 1,500 degrees, because of the cold film which adheres to the plate. But this is not the reason. The fact is that the conductivity of the plate is so great that it cannot attain a temperature much above that of the water at the other side. That the gas is quite competent to heat the plate in spite of the film is demonstrated in a few seconds by letting the plate become dry. Indeed, the difference in temperature of the "water skin," as we may call it, and the "fire skin" depends not at all on the conductivity of the plate, but on the absorbing and emitting power of the plate surfaces. Sir John Durston's experiments brought this out in the clearest light years ago. It was shown first by Péclet in his experiments, and subsequently by Williams in practice, that the conducting power of a boiler plate is at least ten times its emitting or absorbing power, and this is the reason why a heat peg cannot be burned off so long as the portion of it inside the boiler is free from

deposit and in contact with the water. It is physically impossible to establish such a heat gradient as 1,500 degrees — 450 degrees = 1,050 degrees in a boiler plate, always provided that there is plenty of water in contact with the plate. To get such a gradient the fire side of the plate would have to be red hot. But this it cannot be. The fiercest heat of a smith's forge has failed to give a gradient of more than 86 degrees Fahrenheit. The real problem which Professor Nicolson has to study is the condition under which maximum gradients may be established in the plate. That is, measured by the water as well as the gas temperatures; and, paradoxical as it may seem, the greater the cooling influence of the water the less may be the temperature difference in the plate, simply because the plate will be kept cool as a whole. The mistake usually made lies in assuming that the plate next the fire must be almost as hot as the fire. It is a fortunate circumstance for steam users that this is not the case. What may happen when water is out of contact with a plate may be seen when a little "flour deposit" forms on the heating surface. Furthermore, it may be pointed out that the gradient, other things being equal, is just the same in the fire box where the heat is radiant as it is in flues where it comes from the gas.

We turn now to Professor Nicolson's experiment—there is but one which really possesses any practical value. It was made with a Cornish boiler built by Messrs. Adamson for the purpose; it was 6 feet 6 inches diameter, 25 feet long, with a furnace flue 4 inches diameter, formed, as usual, of short lengths jointed with Adamson rings; the first 6 feet of the flue from the front end were occupied by an ordinary fire-grate of 19 square feet area. The second portion of flue, about 8 feet long, was lined with fire brick to form a combustion chamber behind the bridge; and the third or back portion, about 10 feet long, was nearly filled up by placing within it a cylindrical water vessel made of boiler plate, which was 39 inches outside diameter, and had its front end closed by a domed end. Thus an annular space, 1 inch wide, 40 inches mean diameter, and 10 feet long, intervened between the outside of the water vessel

and the inside of the flue, and all the products of combustion due to the burning of 1,200 pounds of coal per hour upon the grate were forced to pass through this space. The result was that the gases fell from the combustion-chamber temperature, whatever that was, at the inlet to about 800 degrees Fahrenheit at the outlet end. "About 15 pounds of air were supplied per pound of coal burnt; and, assuming the gas temperature to have been at about 2,300 degrees Fahrenheit in the combustion chamber—where the bricks were glowing hot—and that the average specific heat between 2,300 and 800 of the gases was 0.25, a very simple calculation shows that the heat transmitted across the plates was on the average 34,450 B.T.U. per hour per square foot."

This experiment would have been interesting if only it had been complete. All the important details are lacking. The number of heat units passed per foot per hour are given as the result of calculations only. According to these, the evaporation was at the rate of 38 pounds per foot per hour, a little more than that actually obtained by Thornycroft's with a water-tube boiler. But the actual evaporation does not seem to have been measured—a noteworthy omission. Nor is there one scrap of information supplied as to the number of pounds of water evaporated per pound of coal. We are told that no less than 13.5 horsepower were expended in driving the suction fan by which the draft of over 7 inches water pressure was obtained. This represents, we are told, 4½ per cent. of all the coal burned. Meager as the data are, nevertheless it is possible to arrive at certain conclusions. The total cylindrical surface of the internal drum was about 100 square feet, that of the flue surrounding it practically the same, or 200 square feet in all. Now the lower surface of the flue and the upper surface of the internal drum were useless as steam makers. We must deduct for this about one-third, leaving an effective heating surface, allowing a little for the dished end plate, of, say, 140 square feet. Taking the evaporation at 38 pounds per foot, we have a total of 5,320 pounds evaporated per hour by 1,200 pounds of coal.

That is to say, 4.43 pounds per pound of coal. This is not a result going to prove that we have before us a valuable discovery. Professor Nicolson seems to have jumped at the conclusion that he has attained results as regards rate of evaporation which are unprecedented. In this he is mistaken. It is useless to multiply examples; one will suffice. During the period of the St. Louis Exhibition very elaborate tests were made with a number of locomotives. One of these, a very large Cole compound from the New York Central and Hudson River Railroad, "No. 3000," evaporated without priming 16.5 pounds of water per square foot of total heating surface per hour. The boiler had about 3,000 square feet of heating surface, 50 square feet of grate. It will be an error on the right side if we assume that the fire-box surface was only 2.5 times as efficient as the tube surface. This being so, we have $2.5 \times 16.5 = 41.25$ pounds evaporated per square foot per hour. Lastly, in this connection, it may be pointed out that Professor Nicolson seems to have forgotten Murray's flame bridges, and the circumstance that dozens of plain cylindrical boilers have been set with flash flues, the products of combustion going straight to the chimney through a semi-circular flue, struck from the center of the boiler diameter, and nowhere more than 4 inches or 5 inches from the boiler bottom.

Much remains to be said for which we have not space. We must, however, suggest that Professor Nicolson has mixed speed and quantity in a very perplexing way. It is the purpose of the boiler engineer to reduce the temperature of his gas. The higher the speed, other things being equal, the greater the quantity of gas to be cooled. The experimental boiler was not well calculated for getting the heat out of the gas. Unfortunately, moreover, two experiments were tried at once, namely, the brick lining and the narrow flue space. Possibly on another occasion Dr. Nicolson will suggest a practical form of high gas speed boiler which will be an improvement on all the forced-draft boilers hitherto invented.—"The Engineer," Jan. 22, 1909.

INFLUENCE OF ASH AND SULPHUR UPON BOILER EFFICIENCY.

A recent paper by Mr. E. G. Bailey, Boston, points out the influence of ash in coal upon boiler efficiency, and shows that it depends not altogether upon the amount of ash, but also upon the nature of it. Ash from certain coals, he says, has a very high fusing temperature. It is almost impossible to make any large clinker from it, no matter how much fire you have, while other coals at a comparatively low temperature (the fire not being forced) will give a very bad clinker. This has frequently been blamed on the sulphur. The sulphur itself should not take the blame, because it is a question of the fusibility of the ash. Tar will melt at one temperature, pitch at another, lead at another, and iron at another, depending upon the fusing points of those different compounds or elements. Ash in coal is a good deal the same. It is composed of practically the same things as clay. You take an ordinary paving brick and line your furnace with it, and it doesn't last very long, but the best of fire clay will withstand a very intense heat. The ash in coal can be compared almost directly to the clay with which brick is made. Some of it contains considerable iron and other fluxes, which cause it to melt at a very low temperature and gives a great deal of trouble in burning grates, stopping the air supply, necessitating frequent cleaning of the fire, which condition cannot help but result in a lower boiler efficiency. Every time you clean the fire you lose several per cent. Your boiler is cooled, and in order to obtain the previous furnace conditions several hundred pounds of coal are required. Also, with a higher ash, whether clinking or not, the fire must be cleaned more frequently, and the percentage of loss in the coke that drops through your grate is larger in proportion to the working of the fire and the number of times that it is cleaned. Mr. Abbott made some tests not long ago in which he showed with the same coal that as the ash was increased to 40 per cent, the boiler efficiency was reduced to zero. The United States Geological Survey made some tests at St. Louis, in which they burned some of the refuse resulting from the

washing of coal. I do not have the exact figures at hand, but the ash in that refuse ran 50 odd per cent., and the boiler efficiency obtained was above 40 per cent.

Sulphur in coal is detrimental for two reasons: It is generally combined with iron, and the iron causes the clinker. The sulphur also, being liberated as the coal is burned, undoubtedly has some effect on the boiler tubes, the stack (if an iron stack is used) and the other iron work, but just to what extent this occurs I have no specific data. In a case to my knowledge, where horizontal return-tubular boilers are used at mines which produce coal varying from 0.9 to 4.00 sulphur, there was no practical difference noted in the condition of the boilers. In another case, where low-sulphur coal was burned, an analysis of soot and other accumulation on the outside of the tubes of a Babcock & Wilcox boiler showed nearly 25 per cent. of free sulphuric acid, and sulphates of iron, showing that the tubes had been attacked more or less by the sulphur.—"The Steamship."

SHIPS.

UNITED STATES.

The Newest American Battleships.—The Naval Board on Construction is now designing plans for three types of battleships, two of which contemplate a battery of eight 14-inch rifles. The third design, according to preliminary plans, will be for twelve 12-inch guns. In the tentative plans for the battleship carrying 14-inch guns the displacement will be 25,000 tons. The third type of battleship will have, according to the preliminary plans, a displacement of 26,000 tons, in order to carry the twelve 12-inch guns, as compared to the ten 12-inch guns of the *North Dakota* and *Delaware,* now under construction. The Board of Construction will soon have the plans ready for submission. The thickness of the side, turret and barbette armor of the 26,000-ton vessel will be slightly

less than that of the new 14-inch gun battleship. The calculated speed is of 20.25 to 20.5 knots under trial conditions of load, and but little less at deep-load displacement. It was a question of having 12-inch guns on these new vessels, disposed as on the *North Dakota* and *Delaware,* which could be done without delay, or of having 14-inch rifles on the *Florida* and *Utah* with a delay of about six months. The Newport Conference approved both recommendations, and in the future battleships would be equipped with the design for four turrets of 14-inch guns. Both the *Delaware* and the *North Dakota,* 20,000-ton vessels, now under construction, will be the largest vessels up to the present time in the United States Navy. They each have ten 12-inch and fourteen 5-inch guns in their armament, and are designed for a speed of 21 knots. The Bureau of Ordnance is preparing for the manufacture of 14-inch guns. Rear Admiral Mason, Chief of the Bureau, asks Congress for a small appropriation to enable the Naval Gun Factory to prepare for the work.—"Nautical Gazette."

New Military Masts for All Batteships.—The Bureau of Construction and Repair is making preparations for the work of installation of new military masts on the ships of the Battleship Fleet during the coming fiscal year. The masts that have been thus far put in have been mainly on ships that were originally constructed with but one mast—such as the *Idaho, Iowa, Mississippi, Oregon, Indiana* and *Massachusetts.* It was obviously not necessary to tear out construction work and overhaul these ships in order to put in the new masts. There was space available for them, and the fire-control installation could be put in just as in a new ship. With the new ships under construction, the *North Dakota, Delaware, Michigan* and *North Carolina,* it was only necessary to effect a change in the contract, and as the ships were constructed the new masts and fire-control systems went in as new and original work. To put the new masts in the fine, large ships of the Battleship Fleet will be a huge task, and one that will involve cutting into a good deal of very substantial work. To do so before considering all questions involved in the use of the new masts would be unwise,

and so there is to be a sea-going test to determine how much vibration occurs on the mast under ordinary conditions at sea. This test will be in charge of Naval Constructor Robinson, and the ships to be used will be the *Idaho* and *Mississippi*. The cruise will start from the League Island Yard about January 15.—"Nautical Gazette."

BRAZIL.

Brazilian Battleship Minas Geraes.—By courtesy of Sir W. G. Armstrong-Whitworth & Co., Ltd., we illustrate the first-class battleship *Minas Geraes*, launched from their Elswick yard a few weeks ago for the Brazilian Government.

The main features of the *Minas Garaes* are as follows: Length, 500 feet; breadth, 83 feet; with a displacement approaching 20,000 tons on the normal draught of 25 feet. The guaranteed speed of the vessel is 21 knots, and the bunker capacity is 2,000 tons, which is sufficient to give a very large radius of action at a moderate speed. Oil fuel is arranged for in addition to the coal.

The armor, which is being manufactured at the company's works at Openshaw, Manchester, is of the Krupp cemented quality, with a main waterline belt 9 inches in thickness, slightly tapered fore and aft.

The armament consists of twelve 12-inch guns, twin-mounted in six barbettes. Four of these barbettes are carried on the upper-deck level, one forward and one aft, on the center line of the ship, and one amidships on each broadside. In addition, two barbettes are carried at a higher level on the center line, firing over the other two center-line barbettes, special arrangements being adopted to protect the latter when the upper guns are firing over them. This arrangement admits of eight of the 12-inch guns being fired ahead or astern, or ten 12-inch guns on either broadside at one time. The secondary armament is the most powerful in any battleship, and consists of twenty-two 4.7-inch guns, fourteen of which are carried on the main deck behind the protection of the citadel armor, the other eight being carried in well-protected positions at a higher

level. There are, in addition, some 3-pounders and smaller guns.

This, and the other vessels now building for the Brazilian Navy, are all being constructed under the supervision of a commission sent from that country.

On the occasion of the launch Admiral Bacellar said the *Minas Geraes* was a proof which could not be gainsaid of the superabundant energy of the great English nation. It was an overwhelming proof of the progress which England had made in industry, in art, in professional skill. Again, was it not an eloquent proof of the confidence which the firm of Armstrong had known how to inspire in the mind of the great nation of Brazil? That confidence had been won by the unsurpassed correctness with which they have fulfilled their contracts in the past, and had led to their being entrusted in the present with the greater part of the program of near £10,000,000 sterling with which Brazil was beginning her naval reorganization.—"Page's Weekly."

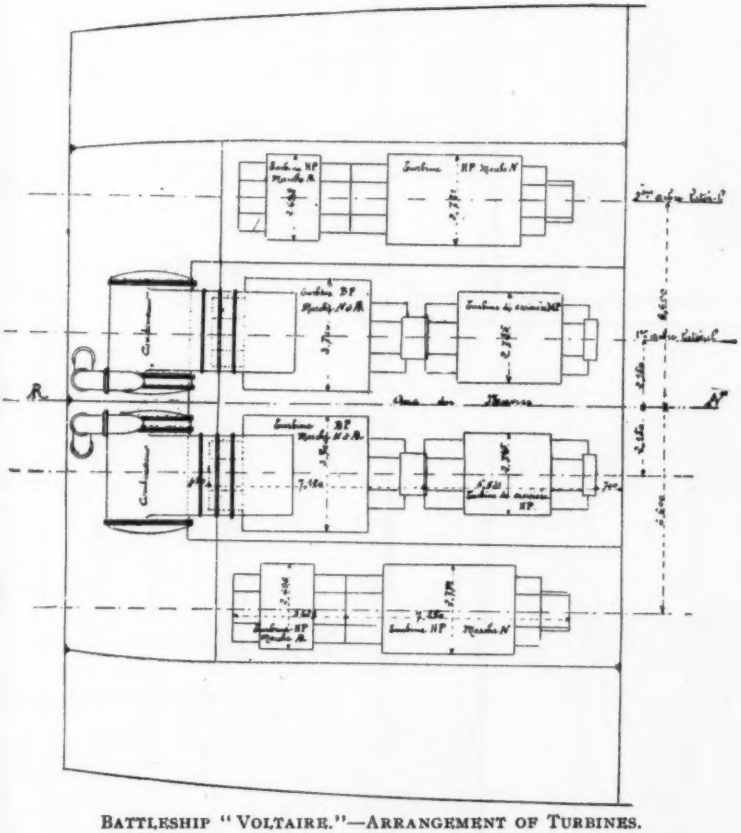
FRANCE.

The French Battleship Voltaire.—We gave in a previous number an account of the successful launching of the *Voltaire* on the 16th of January at the works of the Societe des Forges et Chantiers de la Mediterranée. The *Voltaire* is the first of the six new battleships for the French Navy. We now desire to give our readers an account of the principal features that distinguish the *Voltaire* and her sister ships. The general dimensions are: Length, 145 meters; width, 25 meters 8 cubic centimeters; draught, 8 meters 44 cubic centimeters, with a displacement of 18,350 tons. She is considerably larger than the *Patrie* class, whose dimensions are: Displacement, 14,900 tons; length, 133 meters 80 cubic centimeters; width, 24 meters 25 cubic centimeters.

In truth, these vessels are built along the same lines as the *Dreadnought,* that famous English battleship, the construction of which commenced in October, 1905, and whose trials, in

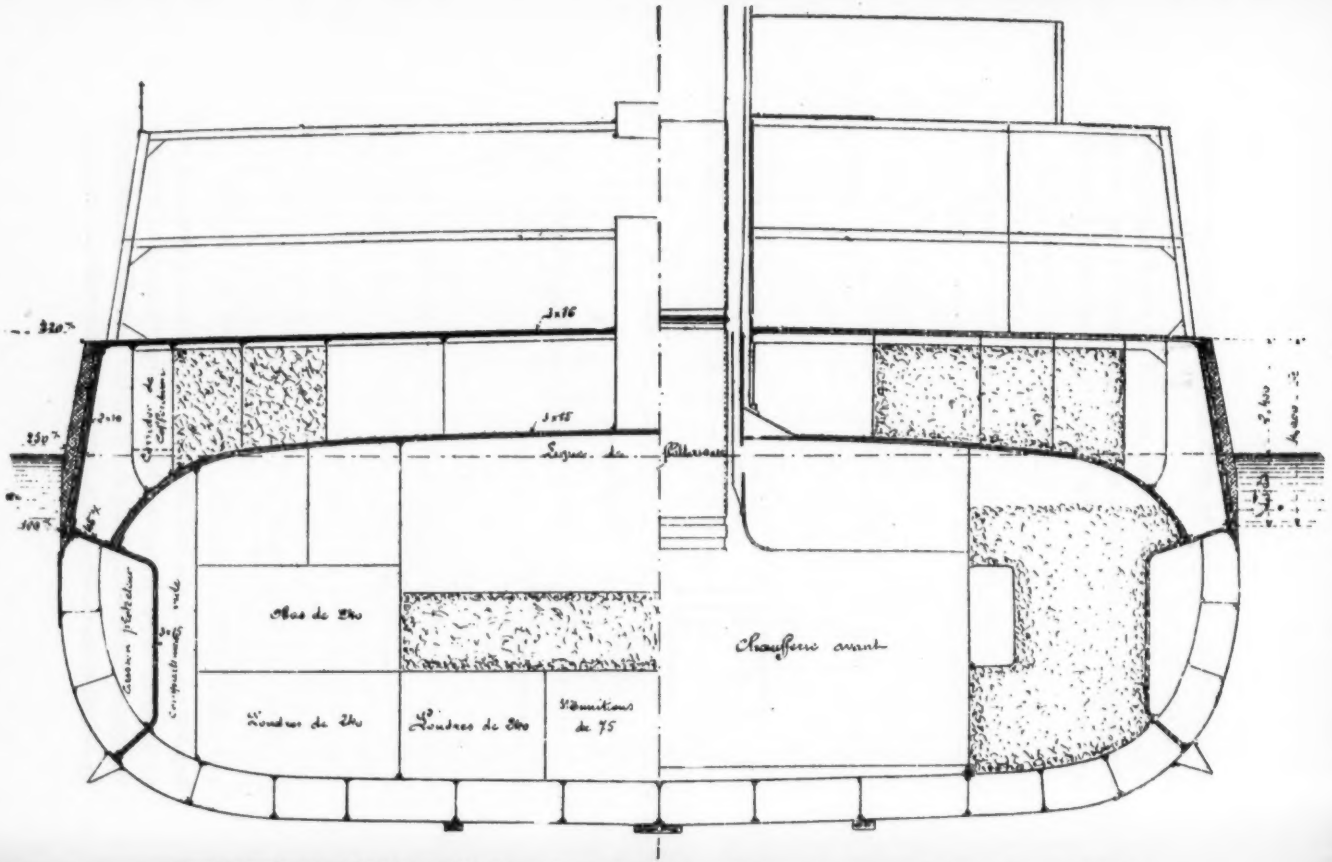
October, 1906, excited in such degree the interest of the entire world.

In reality the *Voltaire* class, as well as the English ships *Dreadnought, Bellerophon,* etc., are the direct result of the experience gained during the Russo-Japanese war. From the



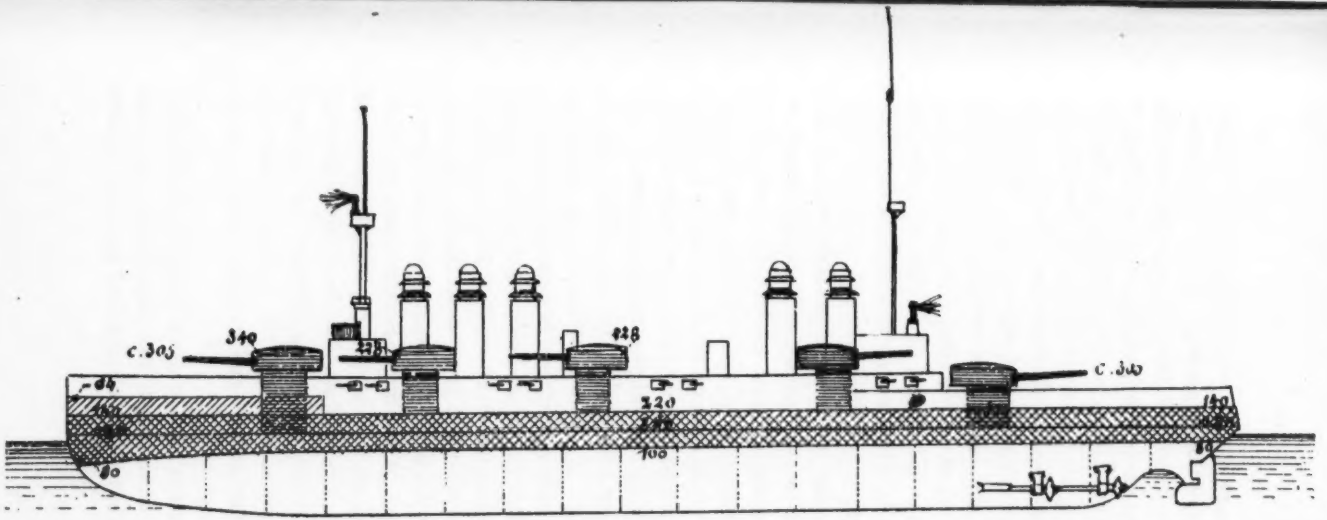
BATTLESHIP "VOLTAIRE."—ARRANGEMENT OF TURBINES.

lessons taught by the sad drama of Tsoushima, French as well as English have drawn analogous enlightenment. It is not, therefore, astonishing that the *Voltaire* and the *Dreadnought* have numerous points of similarity. We concede to our neigh-



THE BATTLESHIP "VOLTAIRE."—HALF CROSS SECTION AT MIDSHIPS AND AT FORWARD BOILER ROOM.

THE BATTLESHIP "VOLTAIRE."—HALF CROSS SECTION AT MIDSHIPS AND AT FORWARD BOILER ROOM.



THE BATTLESHIP "VOLTAIRE," ARRANGEMENT OF ARMOR AND BATTERY.

bors the rapidity and courage with which, obedient to the new idea, they created the type that experience seemed to demand; but, if our decision was less rapid, our courage was none the less, since in one project we put into construction six ships of a type entirely new to us. It is, however, from the English that we took the turbine. It was from the result of a mission to England on the part of some distinguished French naval engineers that our former Minister of Marine, Mr. Thomson, definitely adopted this new method of propulsion for the six units under his program—assuming thus a responsibility that the Societé des Forges et Chantiers de la Mediterranée, the first in France to adapt its plant and personnel to the new idea, did not hesitate to share.

The accompanying plan shows the arrangement of the machinery. It consists of two groups of turbines placed on four shafts, in three separate engine rooms. On each of the outboard shafts is a high-pressure ahead turbine and a high-pressure astern turbine. On each of the inner shafts is a low-pressure turbine (ahead and astern), where the steam is utilized after passing through the high-pressure turbines. On these same shafts there are also smaller cruising turbines, which permit an economical use of steam at moderate speeds. The two groups of turbines have a combined horsepower of 22,500, which will give a speed of nearly 20 knots, against that of the *Patrie* type, whose speed is only 18 knots, with 18,000 I.H.P.

Although the turbine is a point in common on both the *Voltaire* and the *Dreadnought,* there are also important differences between the two vessels. While the one-caliber idea is carried out on the *Dreadnought,* on the *Voltaire* the main battery is of two different calibers. The *Voltaire* has four 305-millimeter pieces in two turrets on the center line forward and aft and twelve 240-millimeter pieces placed in six turrets. There are also 24 pieces of smaller caliber, and 2 under-water torpedo tubes complete the armament.

The protection of the *Voltaire* is also arranged in a different way from that of the *Dreadnought,* and though the latter has thicker armor than the vessels which preceded her, the *Voltaire*

has the opposite tendency. The armor belt, which is higher by 20 cubic centimeters than that of the *Justice,* is thinner (250 millimeters in place of 280 millimeters).

The protection against torpedoes is assured by a double-closed caisson, placed on each side above the double bottom and immediately below the armor belt. This caisson, which is seen on the transverse section, runs the whole length of the vessel; divided transversely from side to side, it is designed to localize the effects of the explosion of a torpedo which would strike the vessel below the armor belt. This protection, which also exists on the *Dreadnought,* was first applied by the Forges & Chantiers de la Mediterranée on the armor-clad *Cesarevitch,* built before the *Dreadnought,* and it was due to this fortunate arrangement that this Russian vessel several times owed her safety during the Russo-Japanese war.

We may also cite, as a distinctive feature of the *Voltaire,* the reduction of superstructure by the absence of bridges and pilot house, interesting innovations which in reducing the target offered by the vessel make her less vulnerable. This reduction of superstructure, as well as the omission of the ram, give to the *Voltaire* an original profile quite different from her predecessors.

We have enumerated the great importance of the dimensions, the substitution of turbines for reciprocating engines, the enlargement of the battery, the protection against torpedoes, the reduction of superstructures. Altogether with all these advantages, which constitute a very considerable progress over the different types of battleships now in service, the *Voltaire* and her class, united in one homogeneous squadron, will make an instrument of the first order in the service of our national defense.—"Le Yacht."

GREAT BRITAIN.

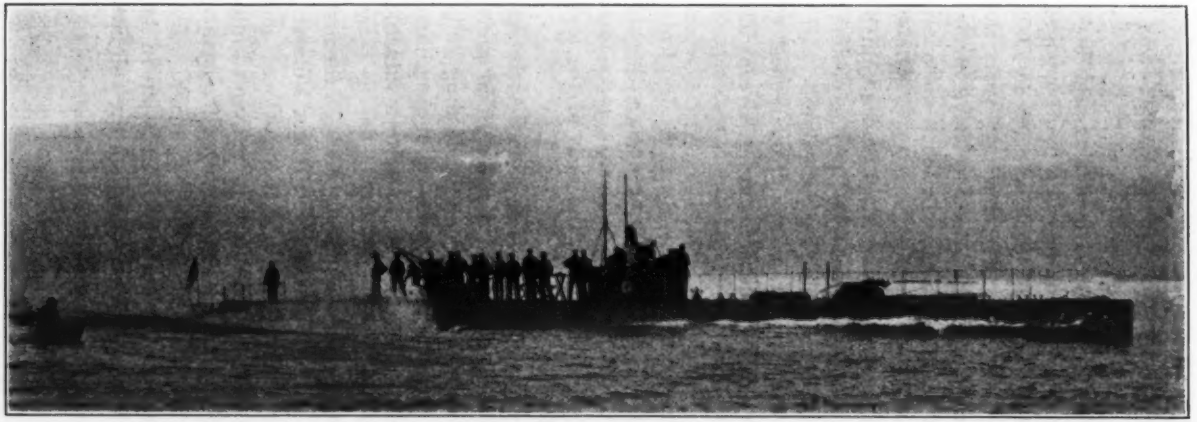
H. M. S. Collingwood.—In the presence of a large number of Admiralty officials and distinguished guests, Mrs. Asquith named the latest battleship of the *Dreadnought* class at Devon-

port Dockyard on Saturday last. The *Collingwood* is the ninth ship of this class to be put afloat, and as the first one was not commenced upon till 1905, the output has been at the rate of three ships a year—a rate which has hitherto given us superiority over our rivals. There is still one more ship of the *Dreadnought* type in hand—the *Vanguard*—which is being built by Vickers' Sons & Maxim, at Barrow, and we believe that the displacement of this ship will be greater than that of any of the others. There are also the two vessels to be laid down at Portsmouth and Devonport early next year, to complete twelve, as compared with nine ships of a similar type which have been ordered by Germany in the same period.

The new battleship *Collingwood* is the second of the three ships of the *St. Vincent* class, which will comprise the *St. Vincent, Collingwood* and *Vanguard;* and it is probable that the *Foudroyant,* which is provided for in the 1908-09 estimates, will also be of this class.

Her machinery will be supplied by R. & W. Hawthorn, Leslie & Co., Limited, of Hebburn and Newcastle-on-Tyne, and will consist of Parsons turbines as fitted in the *Dreadnought*. She will be propelled by four screws. The designed horsepower is 24,500, and the designed speed 21 knots. The boilers are of the Yarrow type, and are adapted for either coal or oil fuel. The normal bunker capacity for coal is 900 tons, and the maximum 2,000 tons. The oil-fuel capacity has not been made known.

The armor consists of an 11-inch belt amidships. The *Collingwood* will carry ten 12-inch guns, but we are unable to give the number of other guns and torpedo tubes which will be fitted. Very little information concerning new battleships is now available, and only the principal dimensions and features can be given.—"The Engineer."



THE ITALIAN SUBMERSIBLE BOAT "FOCA."

The above view illustrates the Italian submersible boat *Foca*, which we briefly referred to in our article on page 12 of January 15, 1909. We stated through a misapprehension, in that article that the *Otaria* and *Tricheco* had been built by the Fiat S. Giorgio Company. Those two submersible boats were built by the Venice Naval Dockyard, on the designs of Naval Constructor Cesare Laurenti, who is now the technical director of the Fiat S. Giorgio Company. The *Foca*, which is claimed to be the fastest boat of her class, has been built completely by the Fiat Company, also on the designs of Naval Constructor Laurenti. The view shows her running at a speed of 15 knots.—"Engineering."

BOOKS RECEIVED.

"AID TO SHIPPERS."—This is the title of a 72-page book containing a quantity of information of value to all engaged in the export or import trade. The book is issued by OELRICHS & Co., of New York, for more than forty years the American representatives of the North German Lloyd Steamship Company, who, by reason of long experience, are qualified to advise.

The table of foreign moneys with United States equivalents, together with weights, measurements, tariffs, customs requirements, etc., etc., will be found of great value.

"Aids to Shippers" will be sent, postpaid, on request to OELRICHS & Co., Forwarding Department, 5 Greenwich Street, New York.

THE DESIGN AND CONSTRUCTION OF SHIPS.* By JOHN HARVARD BILES, LL. D.—The first volume deals with ship calculations and strength of ships. It comprises 420 6-inch by 9-inch pages and 36 folding plates, the body of the text containing 245 illustrations.

The author, for many years Professor of Naval Architecture at the University of Glasgow and associated in an advisory or consultative capacity with some of the leading shipbuilding companies in Great Britain, is no doubt peculiarly well fitted, both in theory and practice, to write a valuable book on Naval Architecture.

The work is to be issued in two volumes, of which the first only is at hand. It is divided into Part I, Areas, Volumes and Centers of Gravity; Part II, Ship Calculations; and Part III, Strength. The second volume is to be divided into five parts, dealing with Stability, Theory of Waves, Resistance and Propulsion, Design and Construction.

The author does not appear to be especially fortunate in the choice of titles for the different parts in which the volumes

* Reviewed by WM. MCENTEE, Assistant Naval Constructor, U. S. N., Member.

are divided. For instance, Part II of the first volume, "Ship Calculations," might naturally be expected to deal with displacement, stability and strength, and possibly also with resistance, so far as it can be determined by calculation alone; but it has to do principally with displacement calculations, and touches slightly on stability. Calculations for strength and stability, which undoubtedly come under the general term "Ship Calculations," are dealt with in separate parts.

A striking omission from the illustrations of curves representing ships' data, such, for instance, as those for prismatic coefficients, on page 148, is the scale or any figures along the borders of the cross-section paper to give any indication of magnitude of the coefficients or the basis upon which they are compared.

Part III, dealing with the strength of ships, is especially complete, and presents some data and views on transverse strength which are new.

The publishers are CHARLES GRIFFIN AND COMPANY, London, and J. B. LIPPINCOTT COMPANY, Philadelphia. The price is 25s. net.

THE TECHNICS OF WORLD NAVIGATION.* BY E. FOERSTER, Doctor of Engineering. (In German.)—This little volume, in German, 160 pages, 5 inches by 8 inches, is another of that delightful series of handbooks issued under the auspices of Dr. F. Bolte, the director of the great School of Navigation at Hamburg. A short introduction states that never in the history of navigation on the high seas has the world's development of culture made greater demands on the means by which communication by sea can be had. The almost universal introduction of large steel steamships has made it possible to determine beforehand the arrival of passengers, mail and freight, even for long voyages, and makes ocean travel more comfortable and securer than ever before. The ever-increasing demands of commerce call for greater and faster vessels, for the establishment of new steamer

* Reviewed by A. H. RAYNAL, M. E., Associate.

routes and the creation of special types of vessels for varying conditions of freight, waters, speed and size. The increased luxurious and more sanitary modes of living ask for the best accommodations for passengers and crew, and, above all, commerce requires that shipping "must pay," that it may be carried on with economy. This leads to a discussion of the fundamental conditions of construction of steel vessels and shows the most modern methods for freight and passenger ships, followed by a chapter on classification, methods and principal rules by the various Lloyds, treats of freeboard, load lines, bulkheads, double bottoms, displacement, stability, etc., and before the non-technical reader is aware of it he has a pretty clear insight in what constitutes the principal and complex conditions of modern steel ship building, so plain and interesting is the narrative. The mechanism of propulsion by reciprocating engines and turbines is explained, the shafts, propellers, their management on a trip and in port, including all that appertains to ventilation, provisions and steering, also the manner in which freight is taken on and discharged, etc., with special reference to the three great types: freight, passenger and combined freight and passenger steamers. After speaking of the ship-building establishments and their modern facilities and the improved dock arrangements, the author ends with a most interesting chapter on the future demands on ship building as to the construction, sizes and speeds that will be required.

This work is clearly printed and illustrated in the very best manner by many diagrams, cuts and half tones showing the most recent constructions. It cannot fail to be of interest to the layman and make him understand the wonderful details of that marvelous creation, "a modern express steamer," and what is involved in its construction, management and commercial success, but there are many points brought out in a way that will also be of use to the technical constructor, the engineer and the ship owner. It is a valuable addition to the literature on ships.

Published by KONRAD W. MECKLENBURG, Berlin.

ASSOCIATION NOTES.

At the annual meeting of the American Society of Naval Engineers, held at the Navy Department, Washington, D. C., December 31, 1908, the following were elected officers of the Society for the ensuing year:

President, Rear Admiral John K. Barton, U. S. Navy, Retired.

Secretary and Treasurer, Lieutenant Henry C. Dinger, U. S. Navy.

Council, Commander H. P. Norton, U. S. Navy; Engineer-in-Chief Charles A. McAllister, U. S. R. C. S.; Commander W. W. White, U. S. Navy, Retired.

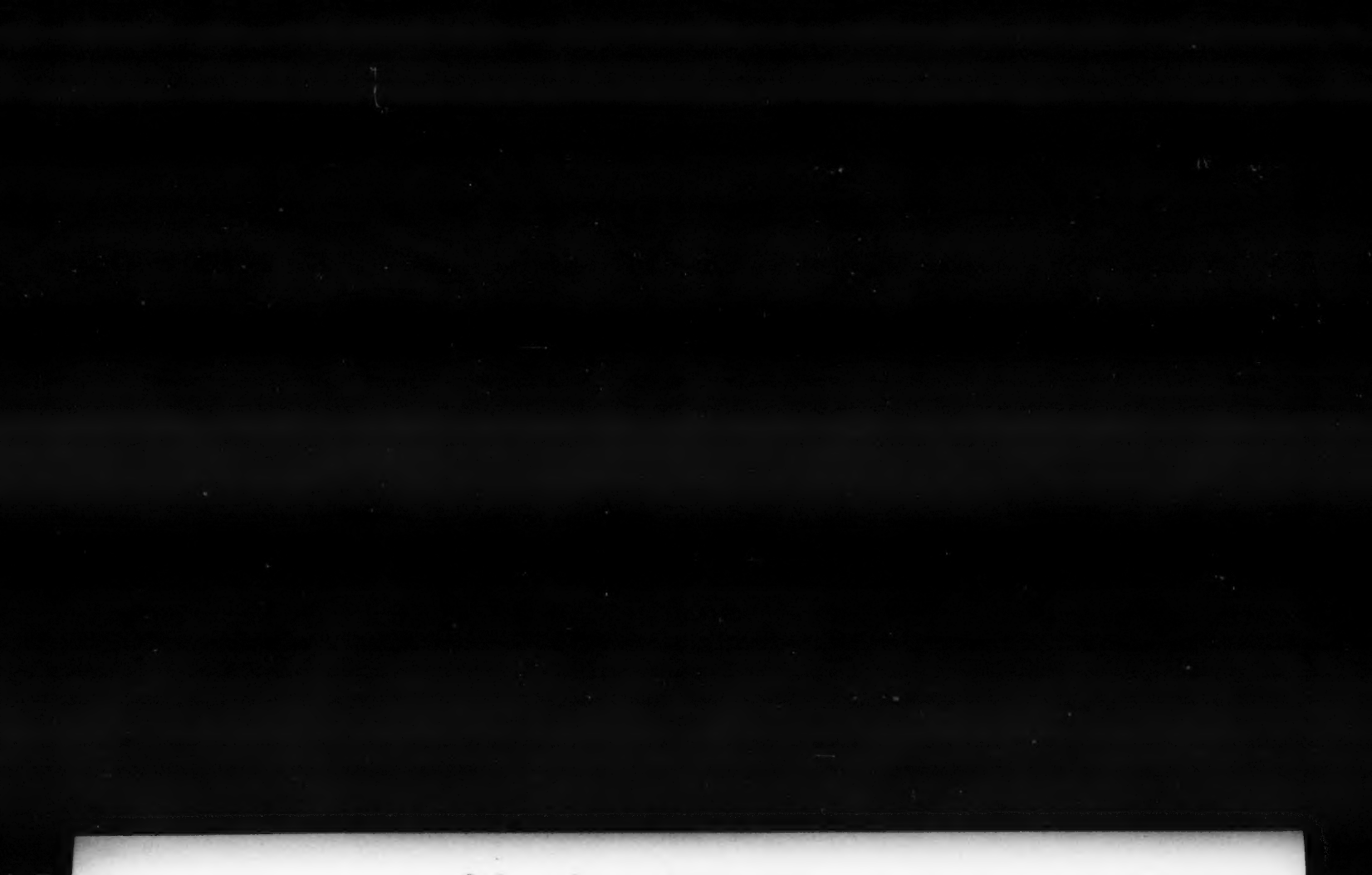
Annual Statement.

The following is the statement of the Secretary-Treasurer for the year ending December 31, 1908:

Received 1908:		
Dues and subscriptions	$3,657.81	
Advertisements	1,393.67	
Sales	146.21	
Interest	262.54	
Publishing	607.35	
B. F. Stevens & Brown, balance on old account	9.22	
		$6,076.80
Balance (cash) January 1, 1908		2,182.69
		$8,259.49

Expended:		
Printing and stationery	$2,577.08	
Engraving	308.43	
Salary, Secretary-Treasurer	900.00	
Employment of Clerk	200.00	
Articles paid for	85.00	
Drafting	10.00	
Commissions on advertisements	21.00	
Premium on bond for contract (N. S. F.)	5.00	
Safe deposit box	5.00	
Postage and expressage	15.00	
Publishing	534.68	
Total expended		$4,661.19
Cash balance		$3,593.30
Balance in bank as per book	$3,553.30	
Cash on hand	45.00	
Cash balance		$3,598.30
Available assets:		
Cash	$3,598.30	
Six (6) $1,000.00 bonds	6,000.00	
Total		$9,598.30
Cash balance, January 1, 1908	$2,182.69	
Cash balance, January 1, 1909	3,598.30	
Net gain for year		$1,415.61

This statement was audited by a committee of the Council and found to be correct.

H. C. DINGER,
Lieutenant, U. S. Navy,
Secretary-Treasurer.

J. K. BARTON,
Rear Admiral, U. S. Navy (Retired),
President.